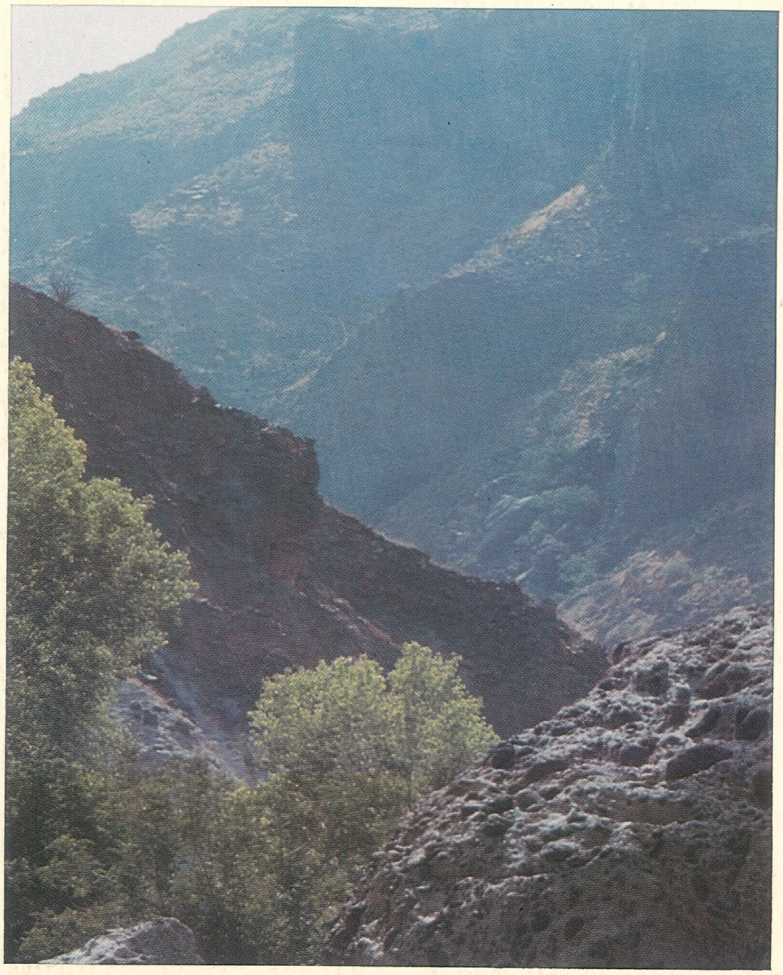
FRESNO CANYON

A NATURAL AREA SURVEY
NO. 10



Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin
1976

The full-color frontispiece is by photographer Reagan Bradshaw and represents but a small part of the work he recorded in the course of the Fresno Canyon area survey. Transparencies of his photos of this and other survey areas have been filed with the natural Areas Survey project, Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin. Mr. Bradshaw is one of the finest nature photographers of the Southwest. His work on these natural areas is sure to increase public awareness of the need to save and protect.

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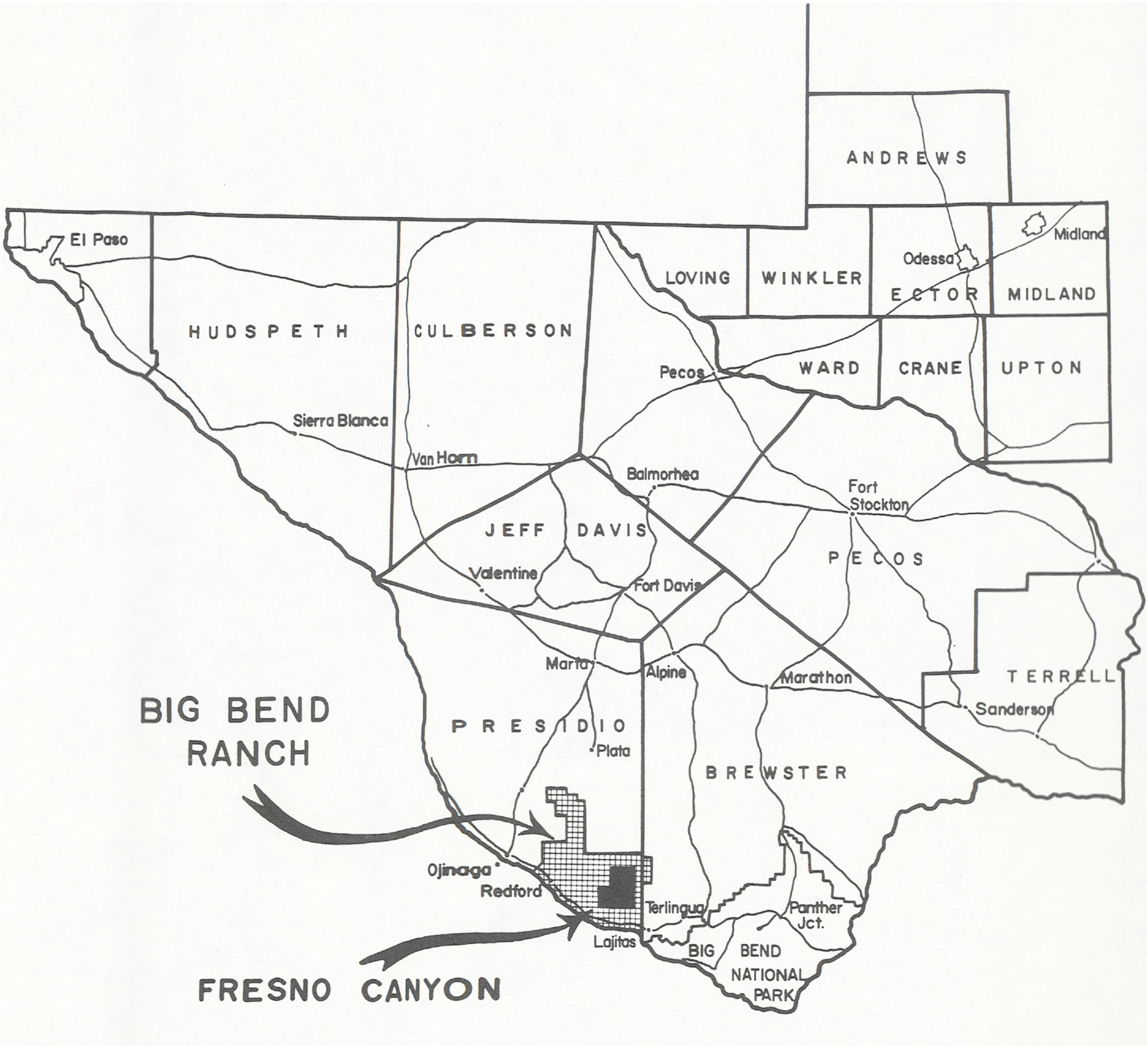
ANDREWS
El Paso
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UPTON
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Van Horn
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Fort Stockton
JEFF DAVIS
PECOS
Valentine
Fort Davis
Marfa
Alpine
Marathon
TERRELL
Sanderson
BIG BEND RANCH
PRESIDIO
Plata
BREWSTER
Ojinaga
Redford
Terlingua
Panther Jct.
Lajitas
BIG BEND NATIONAL PARK
FRESNO CANYON

THE UNIVERSITY OF TEXAS AT AUSTIN
LYNDON B. JOHNSON SCHOOL OF PUBLIC AFFAIRS
AUSTIN, TEXAS 78712

Texas Parks and Wildlife Commission
Pearce Johnson, Chairman
4200 Smith School Road
Austin, Texas 78744

Dear Mr. Chairman:

The Lyndon B. Johnson School of Public Affairs of The University of Texas at Austin respectfully submits herewith its report, Fresno Canyon: A Natural Area Survey, pursuant to the joint request of the Texas Historical Commission, the General Land Office, and the Texas Parks and Wildlife Department, and in fulfillment of Inter-agency Contract (74-75) 1168.

The Fresno Canyon, like each of the other areas undertaken at your request, was scientifically and historically surveyed, mapped, and photographed, which involved the recruitment and direction of a field team of geologists, archeologists, botanists, zoologists, paleoentomologists, ornithologists, cartographers, photographers, landmen, and historians.

Texas is a diverse and beautiful land with a rich heritage and abundant natural and scientific wonders that should be preserved for the wise use and enjoyment of ourselves and of generations to come. As your commission pointed out in requesting this survey, the more significant natural areas are disappearing all too rapidly in Texas. It is our hope that the data gathered here will be instrumental in reversing that trend.

Sincerely,

Don Kennard

Don Kennard
Director
Natural Areas Survey

FOREWORD

The Natural Areas Survey project of the Lyndon B. Johnson School of Public Affairs at The University of Texas presents this study of Fresno Canyon, a unique Texas natural feature. This report is respectfully submitted to the Governor, the Texas Legislature, and the Texas Parks and Wildlife Commission in order that they be more fully informed about the resources of the state.

All studies in this series were prepared by multidisciplinary teams representing the natural and social sciences. Each study presents a comprehensive survey of the plants, animals, and geology of the area, as well as a review of its importance to man, both ancient and modern. The sites were chosen to fall within the definition of natural areas used in the Texas Outdoor Recreation Plan (Texas Parks and Wildlife Department 1975), "natural areas are areas or sites, which, because of their scenic beauty, rarity, recreation value, uniqueness, ecological importance, or cultural value should be protected for posterity."

There are perhaps a few hundred natural areas remaining in Texas, ranging from sections of mountainous land to half-acre sloughs. They can be found among our mountains, plains, shores, and woodlands. Together they could form a network of wildlife sanctuaries and study areas. It is our hope that citizens and state officials will commit themselves to the cause that these areas be preserved as remnants of the natural world and as sanctuaries for the rare and fragile living things which are succumbing to man's increase on this globe. If these areas are overtaken by development, these studies will provide a bare record of the beauty and scientific wonder which was lost.

With the release of this and the companion reports of this year, the list of project areas now stands at thirteen. Other reports in the series are:

Capote Falls
Matagorda Island
Mount Livermore and Sawtooth Mountain
(and supplement)
Victorio Canyon
Blue Elbow Swamp
Devils River
Canadian Breaks
Devil's Sinkhole Area—
Headwaters of the Nueces River
The Solitario
Bofecillos Mountains
Colorado Canyon
Falcon Dam-Thorn Woodland

ACKNOWLEDGEMENTS

Material for this and the four other reports in this series was assembled and edited by Don Kennard. Editorial contributions to the final manuscripts were made by Griffin Smith, Jr., Senior Editor of *Texas Monthly* magazine, Truett Latimer, Executive Director, Texas Historical Commission, Dr. Marshall Johnston, Professor of Botany, The University of Texas at Austin, Curtis Tunnell, State Archeologist, and Edgar B. Kincaid, Jr.

Color frontispiece was by Reagan Bradshaw. Erlene and Linda Hill were responsible for typography and prepared the layout with the help of B. J. Hill. We are indebted to Dr. Keith Arnold, Dr. Stephen Spurr and Ross Shipman of the Division of Natural Resources and Environment, to the Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin, and to Ronnie Fiesler, Barbara Walker, and John McCully of our staff for their assistance in handling the multitude of details and arrangements necessary to produce these reports.

We are especially indebted to Exxon Co. USA whose interest, encouragement, and generous grant of funds made possible the publication of these reports and significantly enhanced the field research effort of this and other projects undertaken by the Survey.

It is difficult to acknowledge, without omission, the time and effort unselfishly given by so many friends of Texas's natural heritage. With a fear that we may have inadvertently missed others, we wish to give special thanks to:

Robert O. Anderson, Robert B. Anderson, Joe Mims, and Ralph Hager of the Diamond A Cattle Company and the Big Bend Ranch

Bob Armstrong, Commissioner of the General Land Office

Jack Burns, Alpine, Texas

Ned Fritz and the Texas Natural Area Survey

Clayton Garrison, Paul Schlimper, Mark Gosdin and numerous employees of the Texas Parks and Wildlife Department

Texas Historical Commission and its staff

Chairman Pearce Johnson and the members of the Texas Parks and Wildlife Commission

Raul and Enrique Madrid of Redford, Texas

Dr. Hugh Meredith, President, and Dr. Mike Powell, Sul Ross State University

Pioneer Nuclear, of Amarillo, Texas

Red Oliver, Steve Kennedy and Mike McKann, General Land Office

George Pool, U.S. Public Health Service, El Paso, Texas

Linda Roark, Terlingua, Texas

Anders Saustrup and the staff of the University of Texas Rare Plant Study Center

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IMPRESSIONS OF FRESNO CANYON

Griffin Smith, jr.

The search for water is the one abiding constant of human life in Trans-Pecos Texas. It has dictated the routes of travelers, the sites of towns, and the likelihood of wresting a living from an obstinately unwilling land. Because the oases are so few they have been treasured immemorially. It seems inconceivable that any, once discovered, could ever be forgotten.

Yet that has been the fate of the nameless perennial stream which flows through a canyon known as Chorro in the uplands north of Redford. Fed by springs bubbling out of basalt porphyry in the eastern Bofecillos Mountains, it drops through two cascades 100 feet and 30 feet in height before coasting lazily along a reed-choked bed toward Fresno Canyon and the Rio Grande. The stream must have been known to prehistoric man, and it was certainly known to early settler C. H. Madrid, who came there in the 1870s and eventually built a ranch house on a fertile terrace near its banks. But in time the Madrids moved to Redford, taking the memory of Chorro Canyon with them. When a topographic survey team "discovered" the stream and waterfalls in 1970, the news came as a surprise to all but the Madrid family and a few hands on the Big Bend ranch, which now owns the property.

The larger waterfall, christened Upper Madrid Falls, has been compared to the better-known Capote Falls by the few visitors privileged to have seen them both. Each is a comforting interruption of the desert's stark monotony. Lacking Capote's monumental scale, Upper Madrid offers instead a miniature forest of lush vegetation that may be the closest thing to Eden West Texas will ever know. Cottonwood, willow, oak and ash fill the narrow canyon, masking the splash pool with almost constant shadow. The stream itself slides in a diamondshaped pattern down a rock face nicknamed "the pedestal," passing rare columbine, wild rye, and maidenhair along the way. Replenished by underwater springs, it flows through a thicket of crumbling logs and grape vines to the lesser lower falls. Animal life that could not last more than hours in the adjacent desert survives trapped, if that is the word, amid the cool and damp perpetual green. The secretive Madrean Cliff Frog, whose cry is heard only when the humidity meets his satisfaction, is found here; so, too, are the Canyon Treefrog and the rare, relictual Trans-Pecos Copperhead.

This fragile ecological island continues to exist by virtue of a lucky accident: the Chorro watershed above the falls is small enough to escape the tumultuous flash floods that regularly rip the vegetation from Capote and other Big Bend canyons like Arroyo Segundo, just two miles north of Chorro. There in 1974, a normally placid perennial stream turned violent from distant rains and sent a wall of mud and water through a group of sleeping campers, killing one. At the head of this spacious canyon, Mexicano Falls is an impressive sight; but the pools downstream are ephemeral, changing from sculptured basins to shallow gravel beds according to the vagaries of floods. Proof of Arroyo Segundo's capacity for destruction can be seen at its mouth, where the junction with Fresno Canyon is clogged with boulders and debris.

Despite the hazards it brings, water is Fresno Canyon's special wealth. A mile-wide valley separates the Solitario from the Bofecillos Mountains, carrying runoff from each into the Rio Grande. The canyon's two sides are dramatically different, not only in their biology but in their geology as well. The eastern, or Solitario, slope consists of steeply-dipping, pale Cretaceous limestone. Devoid of natural surface water, it supports an environment indistinguishable from the Chihuahuan desert norm. The western, or Bofecillos, slope is built of alternating hard and soft volcanic rocks; ground water trapped between the layers emerges to dissect the dark cliffs with mesic canyons like Chorro and Arroyo Segundo. Other springs, always from the west, form tiny ponds within Fresno Canyon proper, attracting migratory birds, butterflies, and a host of waterloving fauna. Between them the bed of Fresno Canyon looks dry; but in actuality water seeps slowly along through moist gravel a foot or two beneath the surface, readily available with a shovel and a little effort.

The botany and zoology of Fresno Canyon each contain elements of the unexpected. Six varieties of rare plants have been discovered, four of them along Fresno Creek itself. Zone-tailed hawks, golden eagles, and the endangered Mexican duck have been observed. The area is rich in bats whose normal range lies much farther south in Mexico; Western Mastiff Bats and Big Free-Tailed Bats both frequent Arroyo Segundo, indicating that colonies may be established nearby. Other species are believed to occur–the Spotted Bat, which, if bats can be considered beautiful, is considered the most beautiful of bats; and the Mexican Long-tongued Bat, which feeds upon the nectar of blooming century plants. Because Fresno Canyon drains into the Rio Grande, it has provided a historic passageway for bears and mountain lions wandering north from Mexico.

To primitive man, the watered canyon must have seemed a far more attractive home than the arid Solitario. That is not, however, saying much: the nearly three dozen archaeological sites now known suggest a long period of bare subsistence, characterized by foraging and small-game hunting under conditions that made the search for food an almost full-time occupation. There is no evidence that the prehistoric inhabitants of Fresno practiced any sort of agriculture or raised domestic animals. Apart from manos, metates, bones, and vegetal remains, however, they left behind a small collection of simple pictographs. One site, whose smoke-blackened roof consists of a remarkable grooved slab of limestone thrust down as the Solitario was uplifted 50 million years ago, has been decorated with colored handprints. Another, which depicts men on horseback, indicates that Fresno Canyon was inhabited at least until Europeans arrived in the region.

European influence was long confined to the Rio Grande; the white man came late to Fresno Canyon itself. La Junta, now Presidio, was well-established when Antonio de Espejo passed through in 1583; and a place called Tapalolmes, near modern-day Redford, was visited by Rabago y Teran in 1747. But Fresno remained untouched. North-south travel, such as there was, flowed for centuries along Alamito Creek, 30 miles northwest of Fresno and nearer to La Junta. This was the route chosen by Espejo on his journey from Santa Fe to the Rio Grande; later it flourished as the Chihuahua Trail, a passageway for American goods before the Civil War, and for American cattle after.

Fresno basked in silence until the twentieth century, when a rugged road from Marfa to Lajitas was cut through to give access for the Terlingua mining district. Mule pack trains (immortalized in the photographs of W. D. Smithers) dodged potholes, forded streams, and circumvented rockslides to make the journey in three days. In 1916, when Pancho Villa and his men hid out in Alamito Creek, U.S. Cavalry reinforcements used the primitive Fresno Canyon "highway" to station themselves at Lajitas against his depredations. Along the route they saw the things we see today: to their right, mountains concealing springs, cool water, and grassy shade; to their left, the Solitario's awesome toothed rim and the three colossal false apertures known as *Los Portales*.

Beside that road, rancher J. F. Crawford built a home in 1918. The spot he chose was sheltered from north winds by the serrated ridge of Rincon Mountain; it was near a spring, of course. Behind a neat stone wall breached by a wooden gate, he laid down hardwood floors and placed a mantel on his fireplace; outside the living room he built a terraced formal garden with an ornamental pool, and in the back, a citrus orchard. In time the house was bought by Harry Smith, who, like Crawford, raised angora goats. Smith stayed until the 1940s, defying climate, predators, and isolation, then sold his land and left.

The Marfa-Lajitas road, now given back to private hands, lies abandoned and impassable through much of Fresno Canyon. The Smith House, as it now is called, is a scene of chilling melancholy. The white man came late to this unconquerable country, and he did not–could not–stay; even the water could not make it his. Nothing is left but the whitewashed shell; the hardwood floors are gone, the fireplace stripped, the windows carried away, the roof in ruins. Thornbushes clog the decorative pool, while in the orchard one last gnarled orange tree inexplicably survives. Over the door a horseshoe rusts.

A BRIEF HISTORICAL SURVEY OF THE BIG BEND AREA

Bruce D. Saunders

Almost hidden in a remote corner of West Texas is a vast area of land that modern civilization has left virtually untouched for decades. The whole region of the Big Bend—bounded on the west and south by the Rio Grande, the Pecos River on the east, and the state of New Mexico on the north—has been a very difficult area to settle. Summer temperatures that can occasionally soar to 55° centigrade (130°F) during the day and then drop rapidly at night, a limited amount of annual rainfall, a scarcity of springs and waterholes, the presence of spectacular but treacherous mountain ranges, all have contributed to the region's lack of early settlers. It is a forbidding area that has attracted only the strongest and most determined individuals who must constantly battle the natural elements found there. Yet there is a beauty and grandeur to the open spaces of this region that the majestic mountain ranges and deep valleys accentuate. Man has been forced to wrestle the land away from the cactus, ocotillo, mountain lions, rattlesnakes, and scorpions that have successfully inhabited the land for centuries. Visitors find the area exhilarating and challenging and often succumb to what columnist and historian Frank Tolbert calls "Big Bend Fever." Walter P. Webb, the noted historian, agreed with Tolbert but pointed out that the malady had an insidious nature because people were often "homesick for a place that could never be their home."[1]

It has always been difficult to exist in this arid land. The early Indian villages were all situated along the banks of the Rio Grande or smaller tributaries to make use of the water and the fertility of the alluvial plains that appeared after the high waters carried soil

Aerial view of Canyon Colorado, better known as the River Road over the Big Hill. This view is to the west, looking up the Rio Grande that can be seen for miles to the left of the also winding road. Until that masterpiece of road construction was completed a couple of years ago, this part of the Big Bend was impassable. Today it is the route of the Camino del Rio. Picture made September 22, 1965.

and deposited it as the floods receded. Life was so precarious that a drought, a crop failure, or another type of natural disaster often destroyed entire villages or forced them to relocate in other areas. Even an environmental shift could upset the delicate balance that allowed the Indians to cling to a subsistence form of agriculture in the river valleys.[2] Archeologists have located early villages along the Rio Conchos, near its confluence with the Rio Grande, and on the right bank of the Rio Grande.[3] The settlement called Tapalolmes, located near the present site of Redford, Texas, was well established in 1747 when Rabago y Teran observed it during his travels. The natives later crossed the river and built a settlement on the left or west bank.[4] Other villages had been observed and described over a hundred years earlier. The intrepid Spanish explorer Cabeza de Vaca crossed the Rio Grande in 1535, but the exact location of his route has been a subject for lively debate among historians, geographers, and geologists. There is little doubt that he visited the La Junta de los Rios (the confluence of the Rio Conchos and the Rio Grande) area, named the local Indians "the people of the cows," erected a cross, and designated the area "La Junta Pueblo de las Cruces."[5] Robert T. Hill, the famous American geologist of the Trans-Pecos region, maintained that de Vaca wandered from a location near the present site of Ft. Davis on a southwestern course that carried him down Terlingua Creek to Lajitas and then across the Rio Grande at or near the famous San Carlos ford. He then continued on a southwestern heading but reversed his course and took a northern route to La Junta.[6] Hill based his findings on de Vaca's accurate descriptions of the geographic and geologic features he passed in west Texas. Hill was unable to understand why a large number of historians had been unable to correctly plot de Vaca's route.[7]

Many of the early settlers of the Big Bend area and the people that lived along both sides of the Rio Grande who were present when de Vaca came through west Texas were cave dwellers. They spent part of their time in dry caves above the river and the rest of it along the rivers and arroyos planting and harvesting crops.[8] A larger and more organized tribe, the Jumanos, were active in the La Junta area from 1650 until the 1770s. They were first critically observed when the Antonio de Espejo expedition passed through the La Junta area in 1582-1583. They were good farmers but never practiced irrigation, a fact that brought starvation as a constant visitor to the tribe. The Jumanos possibly were related to the pueblo-building tribes who spread southward along the Rio Grande. They allied themselves with the Apaches, their former enemies, during the 1693-1715 period, yet there was still a gradual reduction in the size of their tribe during the 18th century.[9] There is very little accurate information available on this tribe, and, as Newcomb states, "of all the Texas Indians, the Jumanos are the least known, and the few facts about their culture we do possess seem to raise more questions than they answer."[10] He concludes that they were "an important outpost of civilization, a pioneer people who had been temporarily successful in establishing settlements on the fringe of Puebloland."[11]

The Jumanos and the other tribes of the southwest were often viewed as subjects for conversion to Catholicism. A number of *entradas* and *visitas* crossed into the Trans-Pecos area, commencing in 1581 when the Fray Augustin Rodriquez expedition reached La Junta on July 6.[12] Composed of three priests, a sergeant, 19 Indian scouts, and 600 head of cattle, sheep, goats, and hogs, its major purpose was to explore the territory and christianize the natives.[13] The Espejo *entrada* left San Bartolome in early November, 1582, with a complement of 15 soldiers, some servants, a priest, and over 100 horses and mules, to rescue the members of the Rodriquez expedition. Espejo, a wealthy Mexican citizen who was attempting to atone for a crime he had committed, financed and led the expedition as it marched up the Conchos River to the Rio Grande. On December 9, 1582, it arrived at La Junta, where the horses were rested for eight days before it headed northward to El Paso del Norte.[14] Espejo eventually led his men farther north to Santa Fe, then east to the Pecos River, down it to the Sheffield Crossing, west to Kokernut Springs (Alpine), and then down Alamito Creek to the Rio Grande, just south of Presidio, Texas.[15] The Dominquez de Mendoza expedition explored the area north and east of La Junta and travelled up Alamito Creek to Alpine.[16] Both the Espejo and Mendoza expeditions opened a new trade route from Mexico to the United States that remained virtually unused for a century and a half.

An American expatriate was the first man to realize the value of the route that the early explorers had found. Dr. Henry Connelly was a Kentucky physician who moved to Chihuahua, Mexico in 1828. He worked as a clerk in a retail store for a Mr. Powell, saved his money, and later bought the business from Powell. Dr. Connelly left Mexico in April, 1839 via the Rio Conchos to La Junta, crossed the Rio Grande, and headed up Alamito Creek. Eventually he reached his destination, Independence, Missouri. There he loaded either pack mules or a wagon train with goods to sell in Mexico. His first round trip lasted 16 months and was very successful. With Edward J. Glasgow, another American expatriate in Chihuahua, he formed a partnership that continued in

The Crawford Ranch and small farm in Fresno Canyon, lower part of Brewster County, about 1918. It was in an isolated location, but several Army mule pack trains passed by every week, going to and from Lajitas when a cavalry troop was on the Rio Grande. Through the Fresno Canyon was the main route between Lajitas, Terlingua and Marfa then, but not after 1920. Mr. Crawford had the largest goat herd in this part of the Big Bend, and he also grew the first citrus fruit in this part of Texas (oranges and lemons).

a profitable manner until the end of the Mexican War in 1848. Connelly married a Mexican woman and fathered three sons before he moved to the United States States just after the Treaty of Guadalupe-Hidalgo was signed. In 1849 he settled in the New Mexico Territory where he purchased the largest mercantile store in the region. In 1861 and again in 1864, President Abraham Lincoln appointed him territorial Governor, a post he held until the time of his death in 1866.[17]

Connelly's Trail, better known as the Chihuahua Trail, opened a prosperous era for the Missouri merchants and for the Rio Grande Valley area near La Junta and Presidio. After the Rio Grande was finally and firmly established by the Treaty of Guadalupe-Hidalgo as the boundary between the United States and Mexico, new residents began slowly to settle along the river in order to profit from the growing commerce between the United States and Mexico. One of the earliest settlers was Ben Leaton who relocated near the San Jose Mission in 1848 on some land that his wife, the former Doña Pedraza, had purchased in 1833. Leaton, who was born in Kentucky and later lived in Chihuahua, opened a very lucrative trading post, El Fortin. Later called Fort Leaton, it attracted business from the Indians, American travellers and merchants, and Mexicans who crossed the river to trade. Leaton, a mysterious man, disappeared in the early 1850s, setting off a long and complicated series of court battles over his land.[18] Fort Leaton is in the process of being reconstructed on its original location several miles south of Presidio near the mouth of Alamito Creek.[19]

Fort Leaton, the outpost of civilization in the Big Bend region, was a favorite stopping point for Americans who crossed the Chihuahua Trail or who were exploring the area. One of the first groups of visitors included Colonel Jack Hays. He had been commissioned, along with Samuel Highsmith, to find a new trade route between San Antonio and El Paso del Norte. Businessmen in San Antonio had raised over $800 to finance the expedition of 35 Texas Rangers and Indian guides. They left the Alamo City in August of 1848, undoubtedly never believing that they would almost starve to death before reaching the security of Fort Leaton in late October.[20] Samuel Maverick, a veteran of the Mier Expedition and the

Mexican War, kept a detailed diary that indicates the problems they encountered. It took a month to reach the Devil's River. After crossing it, they entered the Big Bend region and became lost. Maverick's diary illustrates their suffering. September 29: men were "crawling like flies on side of mountain." October 2: "To banks of the Rio Grande, where we killed and ate a panther." October 4: "Mustang meat in request." October 7: "No food. Here we begin to eat bear grass." October 10: "Killed a mule. Meat poor and tough." On October 19, the weary band reached the small Mexican town of San Carlos, mainly through some directions a group of Indians had given them, and obtained bread and milk to restore themselves.[21] They travelled north from San Carlos, crossed the Rio Grande, and spent 16 days at Fort Leaton recovering from their ordeal and resupplying for their return trip to San Antonio. Hays ruled out any thought of a continuation of the trip to either El Paso de Norte or Chihuahua City.[22] Although the Hays-Highsmith group was the first expedition to reach Fort Leaton from San Antonio, the results of the trip were not impressive or satisfactory. One member of the party, Dr. Wahm, went insane and deserted as the expedition wandered aimlessly in the Big Bend region. The Indians found and cared for him and later permitted him to return to San Antonio a year and a half after he first left with Hays and Highsmith.[23]

The year after the Hays trip, the United States Army, eager to find a shorter route to the west, dispatched Lieutenant W. H. C. Whiting of the Corps of Engineers to seek a safe route from San Antonio to El Paso del Norte. He had difficulty traversing the Trans-Pecos area but reached Fort Leaton in six weeks. He resupplied there and enjoyed the type of hospitality that made Ben Leaton famous throughout the west. Whiting recorded in his diary that he dined on stewed chicken with chili, tortillas, roast turkey, frijoles, coffee, and whiskey, with Leaton's famous peach brandy as an after-dinner drink.[24] Whiting and his assistant, Lieutenant W. F. Smith, continued up the Rio Grande to El Paso del Norte and returned to San Antonio via a new route that ran southwest between the Pecos and San Pedro Rivers to Las Moras Creek and then into San Antonio. It was an improved route that covered an estimated 645 miles.[25]

Following Whiting's successful mission, the Army attempted to find a shorter and safer route to El Paso del Norte via the Rio Grande. Captain John Love proceeded from Ringgold Barracks, near Rio Grande City in the lower valley, up the river to a spot he estimated as 1,014 miles from his starting point. He led a company of a dozen men, using a flat-bottomed boat that measured 50 by 16 feet and drew only 18 inches of water. They used this boat for what he estimated to be the first 967 miles, but at Brooks Falls they changed to a smaller boat that took them to an impassable point they believed was 25 miles south of Presidio. While they failed to navigate all the way to El Paso del Norte, they considered they had proved that over a thousand miles of the Rio Grande was navigable, even if only in small boats.[26] Love's report was quickly contradicted in another Army document that stated that the Rio Grande was only ten inches deep above Eagle Pass and thus impassable much of the year. The second report, the work of a small party of Army men under the command of Lieutenant Martin Luther Smith, was based on a trip via flat boats to a point eight miles above the confluence of the Rio Grande and the Pecos Rivers.[27] Despite Capt. Love's optimistic report, the Rio Grande was not the best route from San Antonio to the Big Bend Region, El Paso del Norte, or Chihuahua City.

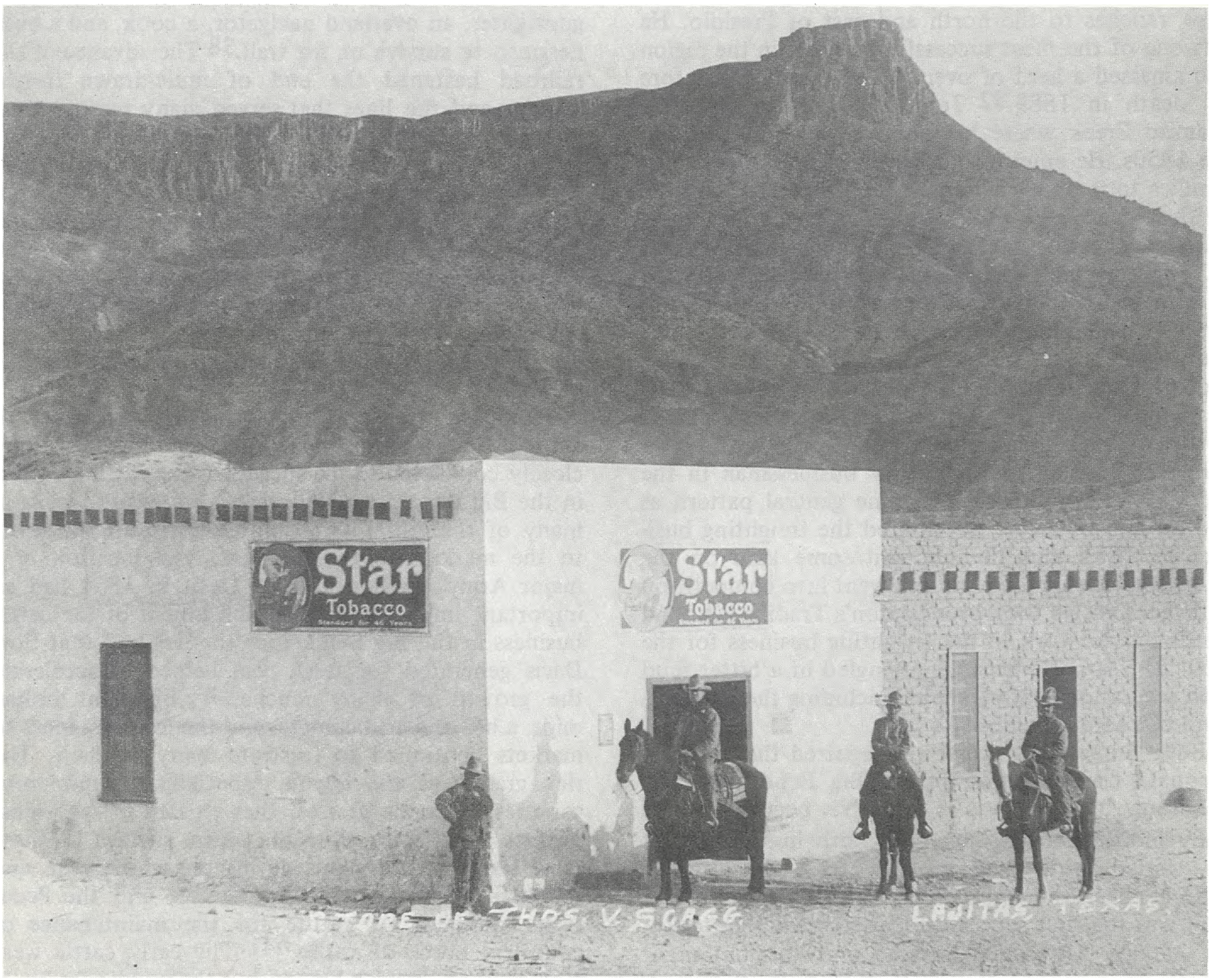
American interest in the exploration of the southwest continued for other reasons. Pursuant to the terms of the Treaty of Guadalupe-Hidalgo, the United States Army organized a number of reconnaissance missions that were ordered to survey carefully the border region along the Rio Grande. John Russell Bartlett was the first Boundary Commissioner, but his poor knowledge of the west, problems with the Indians, disagreements with Mexico, and a shortage of funds sharply curtailed his effectiveness.[28] Major William H. Emory, an astronomer attached to the Topographical Corps of the United States Army, assumed command of the surveying party as it started to work its way south along the Rio Grande to its mouth. Emory faced numerous problems that included the severity of the climate, lack of funds to pay his men or purchase supplies, and the rugged nature of the terrain he had to map. Emory and his skilled assistants carefully classified and catalogued the flora and fauna they found along the length of their route. They were most impressed when they travelled from Fort Leaton south toward the canyons of the Rio Grande. Emory remarked that it was "a section of country which for ruggedness and wilderness of scenery is perhaps unparalleled."[29] They observed that a one-to-three-mile-wide valley extended from Fort Leaton south to the Bofecillos Mountains where it narrowed to form a canyon. Farther to the south, near the present Lajitas Trading Post, Emory reported that the Comanche Pass ford was the "most celebrated and frequently used crossing place of the Indians."[30] He happened to meet Chief Mano of the Apache Tribe who was leading a band of men through the ford to Durango, Mexico.[31] Emory's work in the Big Bend region was the first detailed scientific exploration completed in the Big Bend region, but other men who followed added more information to his collection of samples and observations.

All of these explorations of the area and the continued expansion of American interests convinced several Americans living in Mexico that the border region along the Rio Grande near Presidio and immediately to the south held the promise of commercial success. Milton Faver, like Ben Leaton, came to Presidio after living in Mexico and marrying a Mexican woman. He ran a freight line between Ojinaga (near La Junta) and Meoque and later operated a general store in Ojinaga, but he finally moved to the west bank of the Rio Grande and eventually owned four large ranches to the north and east of Presidio. He was one of the most successful ranchers in the region and amassed a herd of over 20,000 longhorns before his death in 1889.[32] John W. Davis settled near Alamito Creek where he raised horses and cattle in the 1850s. He employed between 15 and 20 Mexican families to operate his ranch. He decided to leave the southwest in 1892 to return to his native North Carolina after the death of his Mexican wife.[33] John W. Spencer, one of Leaton's original business partners, moved with his Mexican wife and large family to the American side of the river in the 1850s to enter the horse-raising business near Fort Davis. The Indians stole most of his stock, so he moved back near the Rio Grande for security reasons, settling north of Presidio and entering the cattle business.[34] John D. Burgess, another early businessman in the Presidio area, followed the same general pattern as Leaton and Spencer. He entered the freighting business in 1851 and then bought some land on the American side of the river and went into competition with Leaton. He took over Leaton's Trading Post and continued to work in the freighting business for the next 20 years. He became entangled in a bitter feud with several of Leaton's heirs, including the new husband of Leaton's widow.[35]

Both Burgess and Leaton recognized the need for adequate transportation in the Big Bend area. The freighting business was a lucrative occupation for many individuals who ran lines both in Mexico and the United States and profited from the growing trade between the two nations. Connelly's Chihuahua Trail was the first successful route connecting northern Mexico with the American midwest, but other routes were needed. In 1869 August Santleben inaugurated a stagecoach route between San Antonio and Chihuahua City via Fort Stockton and Presidio. He made a number of round trips in the 1870s, carrying goods of all types, especially silver from the Mexican mines. In 1876 he attempted to organize a large-scale freighting business in Chihuahua City, but the completion of the El Paso del Norte-Chihuahua City railroad forced him to abandon his plans.[36] Henry Skillman's San Antonio-El Paso mail route, established in 1850, was extended to Presidio on the Rio Grande on a weekly basis in 1870 and brought the area into closer contact with the rest of Texas and the United States.[37] Drivers on the Chihuahua Trail used the prairie schooner as their principal vehicle. It had a bed 24 feet long but was only 4½ feet wide with wooden sides that extended to a height of 5½ feet. The rear wheels were almost six feet high, while the front wheels were a foot shorter. A team of 16 mules pulled an average load of 14,000 pounds. Drivers had to have the skills of a mechanic, a veterinarian, a gunfighter, an overland navigator, a cook, and a businessman to survive on the trail.[38] The advance of the railroad hastened the end of mule-drawn freight wagons and the lines that served many remote areas in the southwest. The Rio Grande area was bypassed in 1883 when the Southern Pacific Railroad crossed the Trans-Pecos region to the northwest of the river, helping to found and promote the towns of Sanderson, Marathon, Marfa, and Valentine along its route. A line did not reach to the Rio Grande until 1930 when the Atchinson, Topeka and Santa Fe linked Alpine and Presidio and provided a connection, via the Mexican National Railroad, to the west coast of Mexico.[39]

Adequate transportation and the location of United States Army posts in the southwest were closely connected to the success of the cattle business in the Big Bend area. Railroads were used to bring in many of the initial herds and to transport the steers to the markets in the midwest. The location of a major Army garrison at Fort Davis in 1854 had an important impact on the establishment of the cattle business in the Big Bend since the demand that Fort Davis generated for fresh beef helped to accelerate the growth of many ranches.[40] Frequent Indian raids, a hot and arid climate, and the long distances to markets continued to frustrate many ranchers. The rich grasses of the region, especially the numerous varieties of grama grasses, that existed in "the most profuse abundance over the entire surface of these table lands, is nutritious during the whole year, and the plains between the Rio Grande and the Pecos seem intended by nature for the maintenance of countless herds of cattle."[41] The early cattle were Mexican and Spanish breeds, but these were gradually replaced as the Texas longhorns were brought into the area. The longhorns, which were seen in many colors, interbred with the native stock to produce a large wild animal that could survive on the native grasses without requiring large amounts of water.[42] Early cattle drives were organized in the 1860s, headed not toward the markets in the midwest but along the Chihuahua Trail into Mexico. These drives, which reached their peak in 1868-1869, were safe from Indian attacks but often fell prey to the raids of the Mexican rustlers that attacked along the route.[43] The most prosperous period for the cattle industry in the Big Bend region came in the 1880s. A land rush during the first part of the decade resulted in the formation of many large ranches. J. T. Gano founded the Estado Land and Cattle Company in 1885 on 55,000 acres with 6,000 head of cattle he brought in from Dallas and Uvalde.[44] Meyer Halff started his ranch with 50,000 acres and added more later while Milton Faver in the 1880s controlled four large ranches with between 10,000 and 20,000 head of cattle.[45] The severe winter of 1885-1886 helped to push over 60,000 head of cattle into the Big Bend, but it proved disastrous as they quickly overgrazed much of the open range. The first large-scale cattle roundup was held the following summer, August, 1888, to sort out the strays and to help preserve the rapidly diminishing grasslands.[46] The introduction of barbed wire in 1888 and the appearance of the Hereford about the same time ended the first significant era in the cattle business.[47]

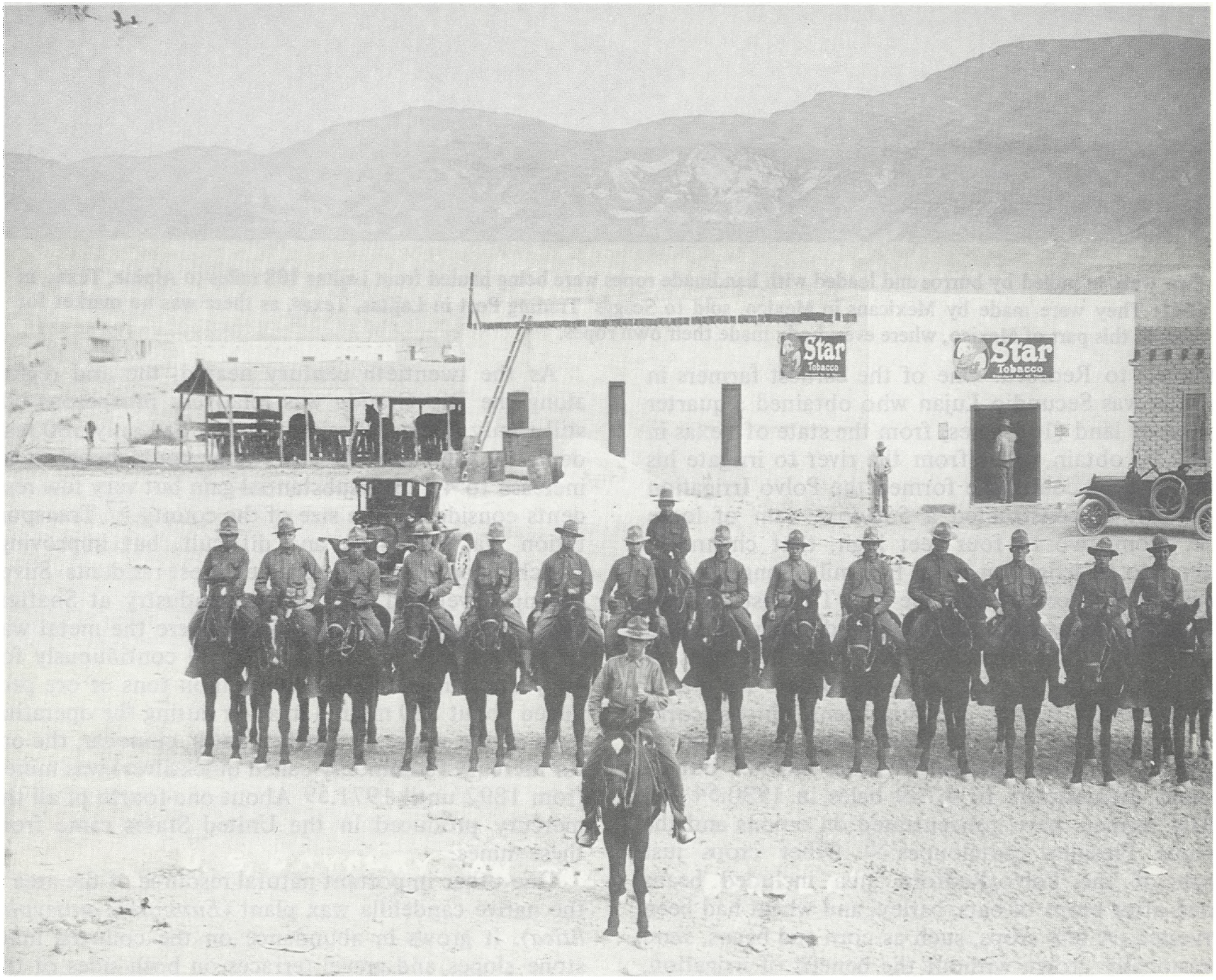
Less romantic, but still economically significant to



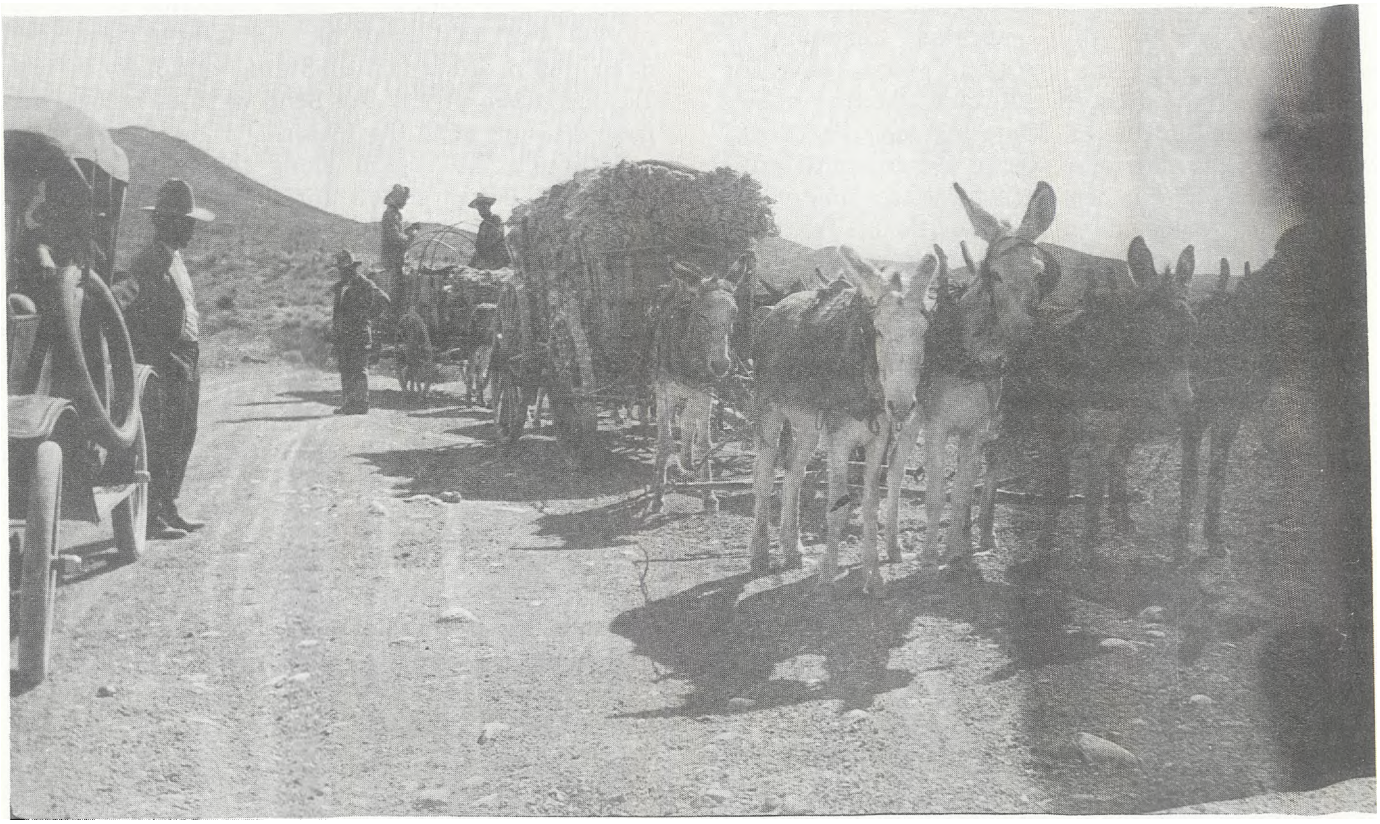
The trading post farthest from a railroad on the Mexican border was at Lajitas, Texas. It was 108 miles from Alpine or Marfa, Texas. From 1911 through 1920, it probably was also the busiest for in that period its regular large Mexican border trade area on both sides of the Rio Grande was made larger by the numerous quicksilver mines nearby. The largest mine at Terlinqua had its own store but the small mines did not. This picture of Thomas V. Scaggs' Trading Post at Lajitas, Texas, was made in 1916. It shows Scaggs at the corner of his store building talking to Texas Ranger Jeff Vaughn, Cavalry Officer Lt. Stilmax, and Texas Ranger Bill Palmer. A troop of the 6th Cavalry and these two Texas Rangers were stationed at Lajitas.

the area, was the sheep industry that Milton Faver founded. He was the first important sheepman to battle the cattlemen for a place on the open range for his flocks in the 1880s.[48] Although the first sheep were introduced in the La Junta region in the 1560s, they did not play a major role in the economy until three centuries later when their total economic value exceeded the value of all the cattle in Texas.[49] Ranchers like Faver fought for the sheepmen, introduced improved breeds, and persuaded others like George Crosson to enter the business. Crosson bought 1,800 ewes from Faver's large flock in the 1880s and was able to enlarge his own holdings to over 20,000 head by 1889.[50] The 1892-1893 drought crippled the sheep business in the Big Bend, and the Cleveland administration's interference with the Wilson-Gorman Tariff of 1894 caused a large reduction of the duty on raw wool that dealt another serious blow to the sheep raisers of the United States, especially in Texas. The sheepmen of the Big Bend did not recover from these disasters until the 1930s.[51]

Although the region along the Rio Grande was somewhat better suited for livestock, a number of successful farms were started in the 1870s. Using water from the river to supplement the limited rainfall on the rich alluvial soils, farmers were able to "raise any crop that grows in Texas," according to an early report from a civil engineer. "Its (the area between Presidio and Redford) yield is enormous, as much as 80 bushels of corn and 50 bushels of wheat being grown to the acre."[52] Irrigation of these fertile lands began in the 1870s just south of Presidio and



This picture was made in 1916 at Lajitas Texas, of Thomas Scaggs Trading Post and part of a troop of the 6th Cavalry. It is not known which troop these troopers belonged to as the troops were rotated. The officer was Lt. Stilmax. The cavalry had its stables at the rear of the trading post when this picture was made but later moved them beyond the second large white building.



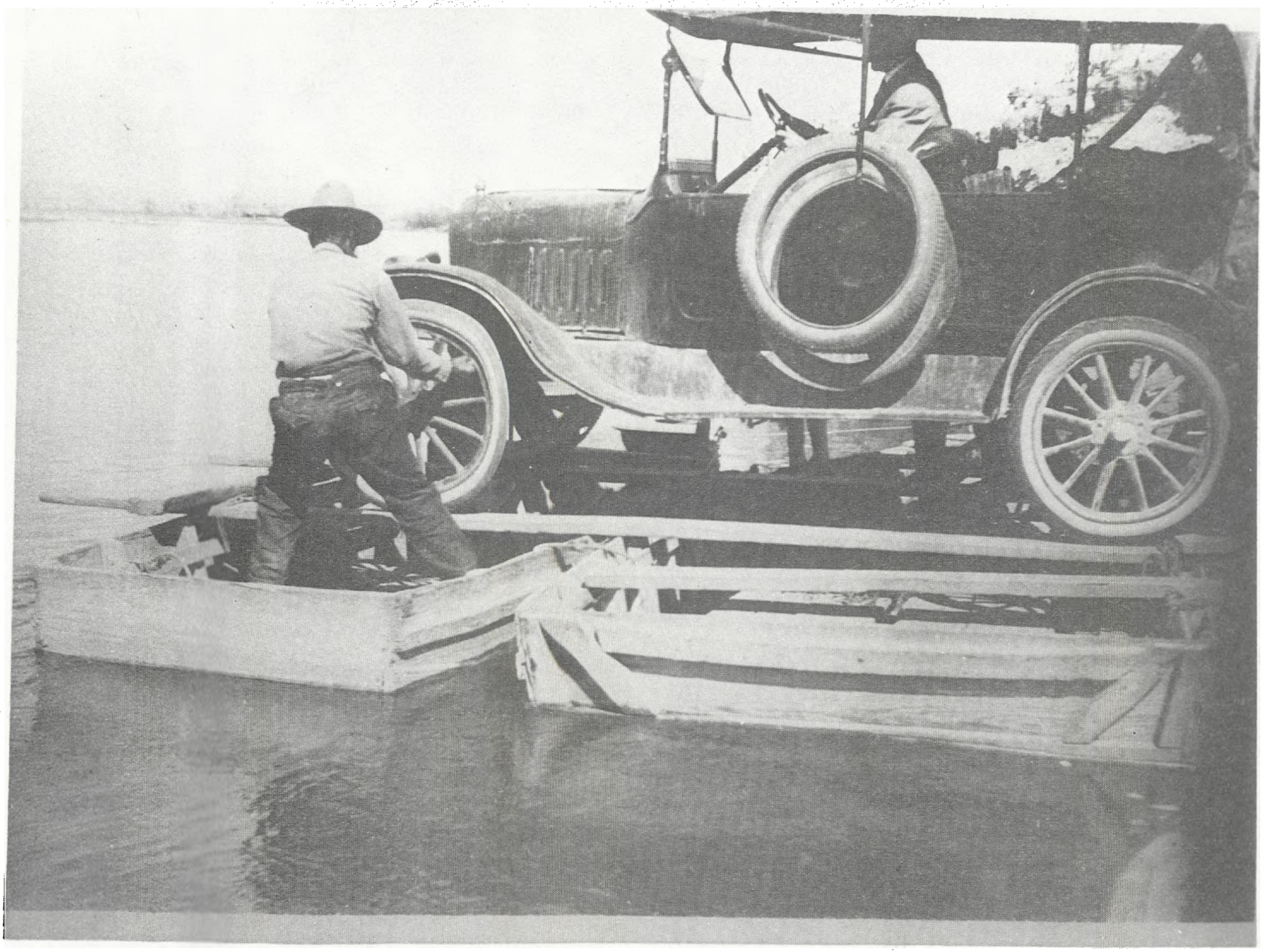
Two wagons pulled by burros and loaded with handmade ropes were being hauled from Lajitas 108 miles to Alpine, Texas, in 1921. They were made by Mexicans in Mexico, sold to Scaggs' Trading Post in Lajitas, Texas, as there was no market for them in this part of Mexico, where everybody made their own ropes.

extended to Redford. One of the earliest farmers in the area was Secundio Lujan who obtained a quarter section of land (160 acres) from the state of Texas in 1875. To obtain water from the river to irrigate his land along its course, he formed the Polvo Irrigation Company. It constructed a 550-foot dam of loose rock, from two to four feet high, that channeled water into an irrigation canal five miles long, six feet deep, and six feet wide at the top. To blast through the hard, igneous rock that he found along the route of the canal, Lujan had to travel over 200 miles to Chihuahua City to purchase gunpowder. He was a very successful farmer, growing beans, onions, corn, and wheat, and later concentrating on cotton.[53] Cotton production totalled 97 bales in 1921 but increased dramatically to 4,789 bales in 1930.[54] Recently farmers have concentrated on onions and the famous Presidio cantaloupes.[55] Other crops just north of the Polvo/Redford area included beans raised after crops of oats, barley, and wheat had been harvested. A few crops, such as corn and beans, were occasionally grown without the benefit of irrigation, usually just north of Presidio where the water level of the Rio Grande was unpredictable and often too low to permit construction of irrigation projects.[56]

As the twentieth century neared, the arid region along the Rio Grande was relatively prosperous but still thinly settled. Presidio County had only 580 residents in 1860 and 40 years later could boast of an increase to 4,125, a substantial gain but very few residents considering the size of the county.[57] Transportation was still slow and difficult, but improving. Ranching and farming occupied most residents. Silver mining developed into a major industry at Shafter, about 30 miles from the river, where the metal was first discovered in 1882 and mined continuously for 40 years. An estimated two million tons of ore produced about $20 million in silver during the operating days of the mines.[58] Farther south, cinnabar, the ore for mercury (commonly called quicksilver) was mined from 1892 until 1971.[59] About one-fourth of all the mercury produced in the United States came from these mines.

One other important natural resource of the area is the native candelilla wax plant (*Euphorbia antisyphilitica*). It grows in abundance on the colluvial limestone slopes and gravel terraces on both sides of the Rio Grande. The plant is harvested and boiled in an acid bath to produce a high-quality wax which is used in chewing gums, floor and auto polishes, crayons, cosmetics, lubricants and a variety of other products. Wax produced in Mexico is supposed to be marketed through the Bank of Mexico, although much of it finds its way across the border and is marketed with the relatively small quantity of wax produced in Texas.[60]

The growing prosperity of the area along the Rio Grande was threatened in the first two decades of the twentieth century when the political and social unrest that spread across Mexico spilled into the United States. In the early part of the century, the Big Bend area had been relatively peaceful since the last raids of the Indians had been effectively ended in the 1880s when a large force of American soldiers had been stationed in a series of forts along and near the border. Francisco (Pancho) Villa, the Mexican bandit and outlaw, often crossed the border into Texas when the Mexican authorities were chasing him. He occasionally hid with his men in the Alamito Creek area, safe from capture but a threat to the stability and peaceful nature of the area.[61] The United States Army was ordered into the area in 1916. A small detachment of cavalry was stationed at the Lajitas Trading Post, and others were garrisoned at Marfa. Aircraft permitted the early pilots of the U.S. Army Signal Corps to patrol the river and locate potential problems before they grew too large to handle.[62] Border raids were common throughout this period.



In 1921 when this picture was made, and earlier, the Rio Grande always had more water than it has today. Then there were not as many large irrigated farms along it. At Lajitas, where this picture was made, occasionally an auto had to cross the Rio Grande, as this Model T Ford of a Texas mining man who had been to San Carlos or some other mining town in the state of Chihuahua. There was a Mexican at Lajitas who had a couple of wooden flat bottom boats that could be converted into ferry boats big enough to cross an auto, as this picture shows.

An estimated 80 Mexican bandits crossed the border during the night of May 5, 1916, to raid both Glenn Springs and Boquillas, Texas. A number of residents were killed, including several American soldiers. President Wilson retaliated by sending a large force to patrol the border region. Another serious raid occurred more than a year later at the Brite Ranch, located near Valentine.[63]

While ranching and farming continued and the border bandits crossed the river to rustle cattle and rob storekeepers, another new industry for the Trans-Pecos area was being established. Robert T. Hill, a geologist, was perhaps the first person who recognized the natural beauty of the Trans-Pecos region, especially the area along the Rio Grande. He planned and led the first successful expedition that explored the Rio Grande from Presidio to Langtry.[64] He ordered the lumber for his three boats shipped from San Antonio to Del Rio where he assembled them and then forwarded them to Marfa via the railroad. Hay wagons carried the thirty-by-three-foot boats the last 75 miles to Presidio. Warnings of impassable boulders in the river, of an outbreak of small pox in Presidio del Norte, and of Mexican bandits who roamed the area frightened off two members of the eight-man expedition before it even got to the river.[65] Although the International Boundary Commission said the river was impassable, Hill set out with five men on October 5, 1899. On the second day of the trip they reached Polvo (in Spanish "dust"), "an appropriately named village" of a half-dozen adobe houses and a store.[66] Stopping to investigate, Hill met the storekeeper, Samuel J. Hensley, who pointed out spots of dried blood on the floor and walls that had resulted when a Mexican bandit had murdered his predecessor several months earlier.[67] Hill and his companions had been warned about a notorious bandit named Alvarado, or "Old White Lip" because half of his moustache was black and the other half white.[68] Although the party did not see "Old White Lip," he was in the vicinity, and several months after Hill had completed his trip, Hensley wrote that Alvarado had robbed a man of $1,200 and assaulted his wife near the area where Hill and his men had camped. Shortly afterwards, the Mexican police shot and killed Alvarado and one of his lieutenants.[69] To prevent any attacks, Hill ordered one man to stand guard over the members of the expedition while they were portaging their boats or when they were sleeping. The 600-foot walls of Colorado Canyon, the geological formations, the wind-eroded rocks, and the size of Santa Elena Canyon all impressed Hill.[70] His descriptive coverage of the river trip that appeared in *Century Magazine*, along with his other field work in the Trans-Pecos area, helped to stimulate interest in the region along the Rio Grande.

Although tourism was increasing and the scientific community had begun to take an active interest in the natural features of the area, ranching continued as the most important economic activity. Older ranches, like the C. H. Madrid spread founded in the 1870s, survived the severe drought of 1892-1893 and were prospering in the 1920s. The Madrids built a water system from a spring to the ranch house and maintained a small orchard of peach, orange, and fig trees, using the irrigation system they had constructed.[71] The D. H. S. Smith ranch, a short distance north of the Madrid Ranch and in Fresno Canyon, grew out of a land grant to the Dallas and Wichita Railroad in 1881. J. L. Crawford later assumed control over it, but sold it to Harry Smith in the 1930s. Smith grazed from 3,000 to 4,000 Angora goats on the ranch, despite the attacks of coyotes, panthers, bobcats, and wolves.[72] Joe Brady bought the large ranch in 1941, installed more water lines, and raised cattle. He used wetback labor that came to him for jobs from across the Rio Grande. The "river telegraph" and possibly "avisadores" kept the work force advised of the location of the Border Patrol and the wages and working conditions on the various ranches on the Texas side of the river.[73] Brady sold the acreage to an Ohio man named Mooney just after World War II. He later sold part of the land to the Fowlkes brothers, owners of the neighboring ranch. Mooney left Texas, although he still owned a part of the land, including the ranch house and the surrounding orchard, both of which have suffered in recent years from a lack of maintenance.[74]

The Fowlkes brothers, Edwin and Manny, came to the Big Bend area shortly before World War II from Jeff Davis County to the north and gradually put together a large (almost 200,000-acre) ranch north of Redford. The severe seven-year drought of the 1950s, among other factors, resulted in the Fowlkes brothers' sale of the ranch to the Big Bend Ranch Corporation, which in the 1960s sold to Robert Anderson's Diamond A Cattle Company. Anderson continues to operate the large ranch, which, by lease or purchase now contains about 320,000 acres, straddling two counties, Presidio to the west and Brewster to the east. He grazes cattle in the Fall and Spring and opens it to hunters during the deer season. An ardent conservationist and naturalist, Anderson has permitted many scientific groups to visit and explore the Solitario, a large partially eroded laccolith that stands virtually undisturbed on the eastern edge of his ranch property. Its outstanding geological formations, archeological sites, flora, and fauna form a large open research site for many scientists.

Life along the river continues at the same leisurely pace that de Vaca must have observed over 400 years ago. But new interest in the scientific treasures of the area, in the beauty of the mountains and the arroyos, and in the desire to enjoy the vast openness of an undisturbed region has brought more people than ever to this remote sector of Texas. Following the modern highway south from Presidio, a visitor can see the green farmland on the alluvial plains of the Rio Grande, pass through the small town of Redford, and approach the first of the numerous breathtaking canyons of the Rio Grande. Driving along the river in air conditioned comfort, it is hard to imagine that de Vaca walked through this area, or that Echols drove camels on this route from Presidio in 1860, or that Colonel Jack C. Hays and his men wandered for 12 days without food just to the south of this spot. Just below Black Rock Canyon, the small village of Lajitas, population nine, slumbers in the warm sun. Again, it is hard to picture elements of the United States Cavalry garrisoned at the Trading Post or the international transactions for cattle being conducted on a sandbar in the middle of the river. It is even more difficult to visualize the Comanche bands as they once swooped down their trail to cross the San Carlos Ford to invade Mexico to loot and kidnap the natives. The full September moon was known as the "Mexican Moon" in Comanche camps as it signaled the time for another raid, but in northern Mexico the same moon was called the "Comanche Moon," and people fled to the mountains to protect themselves and their property.

Farther to the south of Lajitas lies the awesome Santa Elena Canyon that lured Robert T. Hill in 1899 and today attracts thousands of outdoorsmen and adventurers who paddle their canoes and rubber rafts down the river between the canyon's steep walls. It is now part of a 700,000-acre national park that was formed after the land was given to the National Parks Service. Big Bend National Park protects the natural beauty of the area and guards the flora and fauna of this unusual region from destruction. The area just above the park, rich in natural beauty and with a wealth of scientific treasures, would be enhanced by the same type of protection to preserve its rich historical background.

Pictures and captions of photographs in this section are from The Smithers Collection, Photography Collection, Humanities Research Center, The University of Texas at Austin.

NOTES

1. William O. Douglas, *Farewell to Texas: A Vanishing Wilderness* (New York, 1967), 48. This current brief survey was written without the benefit of Ronnie C. Tyler's *The Big Bend: A History of the Last Texas Frontier* (Washington, 1975), a very thoughtful and detailed treatment of the area, which appeared in print after the survey had been completed.

2. J. Charles Kelly, "Factors Involved in the Abandonment of Certain Peripheral Southwestern Settlements," *American Anthropologist,* 54 (July-September, 1952), 382-385.

3. See J. Charles Kelly, "The Historical Indian Pueblos of La Junta de los Rios," *New Mexico Historical Review,* 24 (October, 1952), 251-295 and 28 (January, 1953), 21-51 and also Howard G. Applegate and C. Wayne Hanselka, *La Junta de los Rios Del Norte y Conchos* (El Paso, 1974) 2-23.

4. Kelly, "Historical Indian Pueblos," 28 (January, 1953), 40-41.

5. Cabeza de Vaca, "The Narrative of Cabeza de Vaca," trans. by Frederick W. Hodge, in Hodge, ed., *Spanish Explorers of the Southern United States,* 1528-1543 (New York, 1907), 99-105.

6. Robert T. Hill, "Cabeza de Vaca Crosses the Rio Grande at Last," *Dallas Morning News,* March 11, 1934, 8.

7. *Ibid.*

8. Victor J. Smith, "Survey of Indian Life in Texas," West Texas Historical and Scientific Society *Circular,* No. 5 (1941), 8-10.

9. W. Newcomb, *The Indians of Texas: From Prehistoric to Modern Times* (Austin, 1961), 228-234 and Herbert H. Bolton, "The Jumano Indians in Texas, 1650-1771," *Southwestern Historical Quarterly,* 15 (July, 1911), 66-84.

10. Newcomb, *The Indians of Texas,* 224.

11. *Ibid.*

12. Applegate and Hanselka, *La Junta de los Rios,* 13-14 and Victor J. Smith, "Early Spanish Explorations in the Big Bend of Texas," West Texas Historical and Scientific Society *Publication,* No. 2 (1920), 56.

13. Herbert E. Bolton, ed., *Spanish Exploration in the Southwest, 1542-1706,* (New York, 1908), 138-139.

14. Bolton, ed., *Spanish Exploration in the Southwest,* 161-164 and Smith "Early Spanish Explorations in the Big Bend," 57-58.

15. Applegate and Hanselka, *La Junta de los Rios*, 14.

16. J. Charles Kelly, "The Route of Antonio de Espejo Down the Pecos River and Across the Texas Trans-Pecos Region in 1583; Its relation to Texas Archeology," West Texas Historical and Scientific Society *Publication*, No. 7 (1939), 7 and Smith, "Early Spanish Exploration in the Big Bend," 59-68.

17. William E. Connally, ed., *Doniphan's Expedition and the Conquest of New Mexico and California* (Topeka, 1907), fn. 65, 276-282.

18. J. J. Bowden, *Spanish and Mexican Land Grants in the Chihuahuan Acquisition* (El Paso, 1971), 194-208.

19. For a general review of Leaton, see Levitt Corning, *Baronial Forts of the Big Bend: Ben Leaton, Milton Faver and the Private Forts in Presidio County* (San Antonio, 1967), 19-41 and Elton Miles, "Old Fort Leaton: A Saga of the Big Bend," in Wilson Hudson, ed., *Hunters and Healers: Folklore Types and Topics* (Austin, 1971), 83-102.

20. James K. Greer, *Colonel Jack Hays* (rev. ed., Waco, 1974), 217-225; Averam C. Bender, "Opening Routes Across Texas," *Southwestern Historical Quarterly*, 37 (October, 1933), 118-119; Ralph P. Bieber, ed., *Exploring Southwestern Trails, 1846-1854* (Glendale, 1938), 31-38; William A. Goetzmann, *Army Exploration in the American West, 1803-1863* (New Haven, 1959), 227-228, and John S. Ford, "Jack Hays in Texas," typescript, John Salmon Ford MMS, Box 2Q512, University of Texas Archives, 173-174.

21. Samuel Maverick, "Chihuahuan Expedition," typescript, Samuel Maverick MMS, Box 2R210, University of Texas Archives.

22. J. D. Affleck, "History of Jack C. Hays," typescript, J. D. Affleck MMS, Box 2Q402, University of Texas Archives, 748.

23. Greer, *Colonel Jack Hays*, 222.

24. William H. C. Whiting, "Whiting's Diary," *Publication of the Southern History Association*, 10 (1906), 83-85.

25. Goetzmann, *Army Exploration in the American West*, 228-230.

26. M. L. Crimmins, "Two Thousand Miles by Boat in the Rio Grande in 1850; with a Biographical Sketch of the Army Actions of Captain John Love," West Texas Historical and Scientific Society *Publication*, No. 5 (1933), 44-52.

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THE GEOLOGIC ENVIRONMENT OF FRESNO CANYON, SOUTHEASTERN PRESIDIO COUNTY, TEXAS

Dwight Deal

INTRODUCTION

Fresno Canyon has been cut by Fresno Creek, a southward-flowing tributary of the Rio Grande in extreme southeastern Presidio County. The canyon is of great local interest, for not only has it played an important role in the early settlement of the area, it is extremely scenic and contains interesting geological, botanical, and zoological resources. The Marfa-Lajitas highway, a major north-south route of commerce, passed through the canyon and in the early part of this century was the main supply route for development of the area, both of ranching and of the Terlingua quicksilver mining district. In recent times new highways, much easier to maintain, have been established in the area, extending from Presidio in the west and Alpine and Marathon in the north. The old road through Fresno Canyon has now fallen into disuse.

The canyon separates two significant geologic areas. To the east is the Solitario (Deal 1976a), a remarkable domal uplift exposing intensely deformed older Paleozoic rocks in its center and surrounded by a ring of steeply dipping limestones of Cretaceous age. These limestone sediments form the prominent, light-colored flat-iron cliffs on the east side of upper Fresno Canyon, reaching their most spectacular development in the vicinity of Fresno Peak (Fig. 1). In striking constrast, the opposing western wall of Fresno Canyon is carved through the dark-colored rocks of ancient lava flows (Fig. 2), the cliffs exposing the dissected edge of the ancient Bofecillos Volcano (Deal 1976b). Tributary canyons lead westward from Fresno Creek, cutting farther into the core of the volcanic field. A multiplicity of springs, oases, and waterfalls, fed by groundwater discharged through porous zones in the volcanic rocks, occur in the tributary canyons to the west. Two exceptionally spectacular waterfall areas occur: Mexicano Falls in Arroyo Segundo and Madrid Falls in Chorro Canyon, a tributary to Arroyo Primero.

The Fresno Cañyon area contains an amazing variety of Chihuahuan Desert environments, ranging from the typical to the extreme. The nearly barren arid slopes and valleys along the eastern and southern parts of the Fresno Canyon area are developed on a dominantly limestone and clay substratum. Equally arid and dry volcanic slopes occur along the western side of the canyon, but numerous mesic "islands" with perennial water occur to form scattered oases in the middle of more typical desert environments.

This report is designed to provide a comprehensive overview of the geology of the Fresno Canyon region to be used by both the geologist and interested layman. Although I have attempted to reduce the geologic jargon to a minimum in this report, some

North FIGURE 1 South

Fresno Peak (right skyline) and the Solitario Rim viewed from the western side of Fresno Canyon. Note the prominent flatirons eroded from the steeply dipping Cretaceous limestones. (Photo by Reagan Bradshaw)

users may find it helpful to refer to the *Glossary of Geology* (Gary and others 1972).

The basic resource document describing the geology of the Fresno Canyon area is a Ph.D. dissertation by John McKnight (1968), a condensed version of which is presented with a geologic map in a publication of the Texas Bureau of Economic Geology (McKnight 1970). I have visited the area repeatedly since 1967, spent several weeks in Fresno Canyon in the summer and fall of 1975 with the Natural Areas Survey field parties, and have drawn fairly heavily upon McKnight's earlier work. Those interested in a more detailed description of the geology are referred to McKnight (1968) for a discussion of the volcanic rocks and the western side of Fresno Canyon, and to Herrin (1958) and Corry (1972) for the Solitario. Corry (1972: geologic map; *in* Deal 1976a: geologic map) has compiled the most up-to-date geologic map of the Solitario quadrangle, modifying the work of Herrin (1958) and McKnight (1968). The development of the cinnabar (mercury ore) mining southeast of Fresno Canyon is described later in this report.

PREVIOUS AND RELATED WORK

The 1857 Mexico-U.S. Boundary Survey headed by Emory passed through this area. One of the members of that survey was C. C. Parry (1857), who wrote the first report on the geology of the Bofecillos Mountains. Parry's report was of necessity a reconnaissance and concentrated on descriptions of the striking physiography along the course of the Rio Grande. He described the bolson and pediment development in the basins along the river and the igneous rocks which are exposed in the canyons.

Kimball (1869) traveled southeastward through Presidio as part of a reconnaissance through west Texas and northern Chihuahua. He crossed the Rio Grande Valley and explored the drainage of the Rio Conchos, describing fossils that demonstrated that much of the limestone in the area was of Cretaceous age. He noted the overlying volcanic ash falls and lava flows, which are now known to be of Tertiary age, incorrectly considering them to be Cretaceous and inferring a metamorphic, rather than a volcanic, origin for them.

In the late 19th Century, the discovery and development of mercury deposits along the Terlingua Monocline brought many geologists into the area. A summary of the development of the mercury (cinnabar) resources in the Terlingua District is described by Daugherty (1972) and reproduced as Appendix 3 of this report. The early history of exploration, distribution, and origin of the deposits is described in reports by Blake (1895), Turner (1900, 1906), Spalding (1901), B. F. Hill and Phillips (1902), R. T. Hill (1902), B. F. Hill (1903), Phillips (1905), Kirk (1905), and Udden (1907, 1918). Udden's 1907 *Sketch of the Geology of the Chisos Country* was particularly significant to the study of the Bofecillos Mountains and Fresno Canyon area because it fitted the Terlingua District into its regional geologic setting. More detailed works by Ross (1935, 1937, 1941) and by Yates and Thompson (1959) further explain the geologic factors controlling ore implacement and further described the regional stratigraphy and structure of the area.

The Solitario, immediately east of the Bofecillos Mountains area and Fresno Canyon, received some mention in mineral reports on the Terlingua District. Further information on the Solitario and on the Bofecillos Mountains is contained in companion reports by Deal (1976a, 1976b).

Maps and reports, mostly sponsored by the University of Texas Bureau of Economic Geology (Sellards and others 1933; Goldich and Elms 1949; Seward 1950; Erickson 1953; Lampert 1953; McCarthy 1953; Moon 1953; Rix 1953; Zinn 1953; Dietrich 1954, 1964, 1965; McAnualty 1955; Amsbury 1958; and Ramsey 1961) carried Tertiary volcanic stratigraphy from the north and northwest, providing the basis for McKnight's (1968) work on the Bofecillos Volcano itself.

A geologic report on Big Bend National Park, immediately southeast of the area (Maxwell and others 1967), is a detailed study of the geologic history of that area and allows McKnight (1968) to relate the events of the Bofecillos Volcano to the events occurring within the National Park.

The International Boundary and Water Commission (1955) prepared a series of geologic strip maps at a scale of 1:50,000 along the Rio Grande, extending upstream from Del Rio to a point about 7 km upstream of Lajitas beginning at about the mouth of Fresno Canyon at the southeastern edge of the Bofecillos Mountains. Arenal (1964) made a geologic reconnaissance map of Mexico adjacent to the Bofecillos Mountains area in an investigation of coal and lignite deposits in rocks of Upper Cretaceous age. J. A. Wilson and his students (1952; *in* Maxwell and others 1967) have collected vertebrate fossils from locations outside but near the Bofecillos Mountains. Twiss and DeFord (1967) published some potassium-argon age dates from the rimrock country northwest of the study area, and Wilson and others (1968) compiled more detailed information on the stratigraphic succession, potassium-argon dates, and vertebrate faunas of the same area.

In 1970 field teams from the Topographic Division of the U.S. Geological Survey visited the area while preparing the new 7.5-minute topographic maps of the area, and "rediscovered" Madrid Falls. Since that time numerous scientists, students, and sightseers have visited Fresno and Chorro Canyons, drawing increased public attention to this area. A report by McKann and others (1973) on the Solitario-Fresno Creek area was prepared for the Texas General Land Office and the field work for two Master's theses (McKann 1975; Burns 1976) has been completed in the Madrid Falls area. These theses were concerned with the recreational potential and biology of the area, and no significant original geological work was done for them.

ACCESS

Vehicular access to the area is limited. None of the roads are paved and, even under the best of conditions, a combination of a 4-wheel-drive vehicle and a goodly walk is necessary to reach much of the area. The historic Marfa-Lajitas Highway passes through Fresno Canyon and, although this was once a county-maintained road, it has reverted to private ownership for most of its length. It is only occasionally used or maintained north of the Fresno and Whitroy mines. The county does maintain the southern 11 km (seven miles) as a fairly good graded road from a point on paved Ranch Road 170 (the River Road from Presidio to Big Bend National Park) about one km east of the community of Lajitas on the Rio Grande in extreme southwestern Brewster County. The road extends northwestward into Presidio County to the mines and continues on to Fresno Creek at the Wax Factory Laccolith. The road is maintained only intermittently from the Whitroy and Fresno mines northward through the length of Fresno Canyon to the junction with the county-maintained graded road that runs from Redford through Big Bend Ranch headquarters (Sauceda Ranch) and on through Wire Gap to the Marfa highway. An extremely steep and rocky grade at the north end of Fresno Canyon, where the road climbs up out of the canyon, usually requires a 4-wheel-drive vehicle to ascend.

PHYSIOGRAPHY

The Fresno Canyon area is shown on four 7.5-minute quadrangle maps recently published (1971) by the U.S. Geological Survey: Lajitas, Santana Mesa, Sauceda Ranch, and The Solitario. Elevations range from above 1600 m (5300 ft) on the high limestone rim of the Solitario at the northwestern edge of Fresno Canyon and in excess of 1400 m (4600 ft) on the volcanic mesas to the northwest of Fresno Canyon. Immediately east of the Solitario, in the floor of Fresno Canyon, elevations are approximately 1160 m (3800 ft). The mouth of Fresno Creek where it joins the Rio Grande, about 26 km (16 miles) downstream, is at an elevation of approximately 670 m (2200 ft). The main portion of Fresno Canyon, therefore, has a gradient of approximately 19 m per km (100 ft per mile).

The western side of Fresno Canyon is cut into nearly horizontal alternating hard and soft volcanic and sedimentary units, forming a predominantly stair-step topography interspersed with scattered monolithic mountains formed by resistant igneous intrusive masses. Most of those volcanic rocks were erupted from the Bofecillos Volcano, which had a main vent northwest of Fresno Canyon.

Two major tributaries to Fresno Creek from the west dissect the Bofecillos volcanic field. There has been some historical evolution in the names used for these tributaries. Fresno Canyon has always provided a natural north-south route for travel through the area, and the two main canyons that come in from the west are natural landmarks. Fresno Canyon has also long been a route for Mexican Nationals passing through the area and the western tributary canyons (heading north from Lajitas) became known as Arroyo Mexicano Primero and Arroyo Mexicano Segundo. Some confusion resulted as a result of English-speaking settlement in the area and the southernmost canyon gradually became known as Arroyo Primero, the northernmost as Arroyo Mexicano. The formal names applied on the U.S.G.S. topographic maps of the area refer to them as Arroyo Primero and Arroyo Segundo, respectively. Most of the Spanish-speaking residents still refer to Arroyo Segundo as Arroyo Mexicano.

The northeastern side of Fresno Canyon is cut into the steeply westward-dipping Cretaceous limestones that form the outer rim of the Solitario. Farther south the eastern side of the canyon is cut through gently dipping beds of alternating hard and soft limestones, also of Cretaceous age. Prominent flat irons occur along the Solitario rim (Fig. 1). The main tributary dissecting the Solitario is the Lower Shutup, but much shorter tributaries (Los Portales Shutup and the Righthand Shutup) cut the western rim of the Solitario.

The eastern side of Fresno Canyon is quite dry and is a typical Chihuahuan Desert carbonate terrain. Moisture is available only during or immediately after storms. A notable exception is in the Lower Shutup where two tinajas (bedrock depressions in the canyon floor) usually contain water most of the year. Signifi-

FIGURE 2

View southward down Fresno Canyon toward the Rio Grande and mountains in Mexico. The Smith Ranch ruins are next to the cottonwood trees on Fresno Creek in the right center of the photo. Note the truncated igneous rocks of the Bofecillos volcanic field along the right (western) side of the canyon and localized areas of abundant vegetation which mark seeps and springs.
Photo by Dwight Deal

cantly more water is available on the western side of Fresno Canyon (Fig. 2), particularly in Arroyo Segundo and Arroyo Primero. Mexicano Falls, Madrid Falls, and a number of smaller cascades commonly flow throughout the year. Fresno Creek has a fairly dependable flow in its lower reaches and water can always be found at certain places: the old Smith Ranch ruins, Fresno Falls, Trough Springs, and most of Fresno Creek south of the Wax Factory Laccolith.

CLIMATE

No climate records have been kept in Fresno Canyon itself. A U.S. Weather Bureau station was in operation in Presidio from 1957 to 1969. Dietrich (1965:14-23) presented a fairly elaborate discussion of both regional and local climate of the Presidio and Bofecillos Mountains area north and west of Fresno Canyon. He went into a rather detailed discussion of the Koppen classification of climate and analyzed the climatological data from 27 meteorological stations in Trans-Pecos Texas (Fig. 3). The data from the eight U.S. Weather Bureau stations is shown in Table 1, arranged in order of decreasing station elevation to emphasize the high degree of correlation between elevation and temperature. Mean annual precipitation increases from west to east at stations with comparable elevations and also increases with an increase in elevation. Dietrich (1965:16) applied the Koppen classification to each of these stations and concluded that they all have a dry climate. Four stations have a steppe (*BS*) climate. The three higher stations (Mount Locke, Chisos Basin, and Alpine) have a cold steppe (*BSk*) climate, and the easternmost station, Fort Stockton, has a hot steppe (*BSh*) climate. The other four station have desert (*BW*) climates. Van Horn and El Paso are classified as having cold desert (*BWk*) climates, and Balmorhea and Presidio are classified as having hot desert (*BWh*) climates. Dietrich (1965:16) concludes:

> The steppe climate probably extends to the highest peaks in the mountains of Trans-Pecos Texas. Mount Locke (elevation 6790 feet) has the highest mean annual precipitation and the lowest boundary precipitation value of the eight stations. Its steppe (*BS*) classification would remain unchanged if the station received one-third more precipitation.

Data from those eight climatological stations (Table 1) show that the mean temperature increases 1 to 1.5 degrees Centigrade per 100 m (two to three

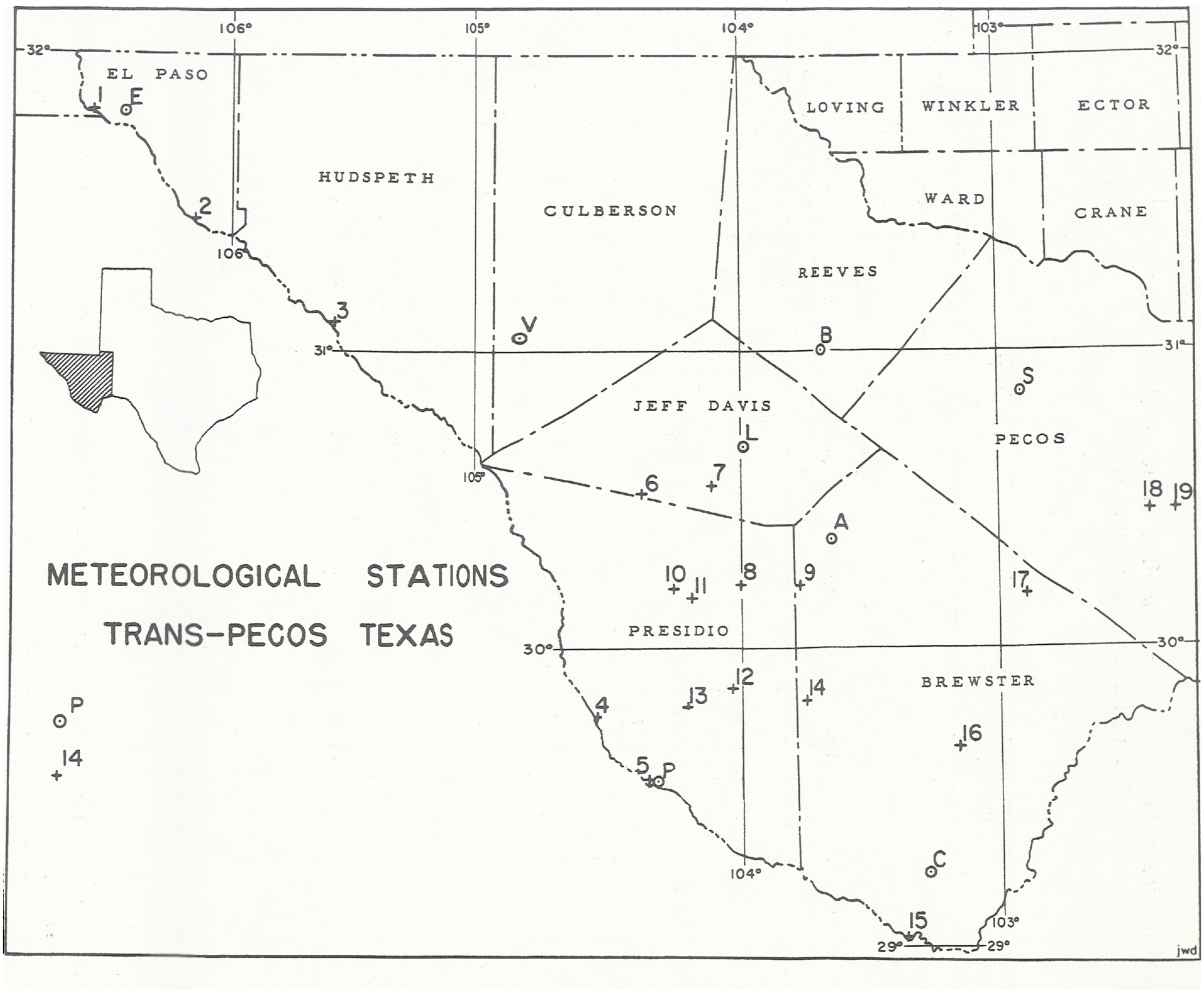

FIGURE 3

Twenty-seven selected meteorological stations in Trans-Pecos Texas (From Dietrich 1965: Fig. 4)

Table 1 — Climatological data, eight U.S. Weather Bureau stations in Trans-Pecos Texas. (from Dietrich 1965: Table 2)

STATION		TEMPERATURE								PRECIPITATION		KOPPEN CLASSIFICATION	
		Extremes				Means							
		High		Low									
Name	Elevation (ft. above MSL)	°F	Year	°F	Year	Jan. (°F)	July (°F)	Annual (°F)	Record period *	Mean annual (inches)	Record period *	r = 0.44t - 3	Climate symbol
Mt. Locke	6790	98	1962	−10	1962	41.7	70.0	57.2	†1945-63	18.72	1945-63	25.17	*BSk*
Chisos Basin	5300	102	1958	− 3	1949	48.9	74.8	63.2	†1948-63	15.19	1949-63	27.80	*BSk*
Alpine	4433	106	1932 1936	− 2	1933	46.7	77.4	63.2	WBN	15.42	WBN	27.80	*BSk*
Van Horn	4050	108	1951	− 7	1962	44.3	80.4	62.8	†1942-63	9.52	1939-63	27.63	*BWk*
El Paso	3918	109	1960	− 8	1962	43.9	81.4	63.6	WBN	7.89	WBN	27.98	*BWk*
Balmorhea	3225	112	1939	− 9	1933	47.3	81.1	65.1	WBN	12.68	WBN	28.64	*BWh*
Ft. Stockton	2995	114	1907 1934	− 7	1911	47.6	82.2	66.1	†1931-60	16.45	†1931-60	29.08	*BSh*
Presidio	2582	117	1957 1960	+ 4	1962	49.8	86.5	69.5	WBN	8.31	WBN	30.58	*BWh*

*WBN: Weather Bureau normal for 1931-1960.
†: Some records missing.
Data sources. — Normals (WBN) from U.S. Weather Bureau (1962, p. 4); other means calculated from data in the office of the State Climatologist, Robert B. Mueller Airport, Austin, Texas.

degrees Fahrenheit per 1000 ft) increase in elevation.

Dietrich also considers data from 19 weather stations maintained by the International Boundary and Water Commission (Table 2; Fig. 3) and has plotted the station elevation for all 27 stations against the mean annual precipitation (Fig. 4). This data indicates that both geographic position and elevation obviously influence precipitation. At stations near the same longitude, the mean annual precipitation increases 5-7 cm per 100 m (2-3 in per 1000 ft) increase in elevation, and, at stations near the same elevation, the mean annual precipitation increases from west to east.

Dietrich (1965:21) calculates that with no change in the mean annual temperature, an 85% increase (18 cm or 7 in) in the mean annual precipitation at Presidio would be required to change the classification from hot desert (*BWh*) climate to steppe. He went on to approximate temperature gradients in the area from the regional data and calculated that the boundary between desert and steppe climate should occur about 1500 m (4900 ft) above mean sea level. If he is correct, then the desert-steppe boundary is near the tops of the higher peaks in the Bofecillos Mountains and the Solitario.

Most of the Fresno Canyon study area is, therefore, typical Chihuahuan Desert hot desert (*BWh*) climate. Perennial and intermittent streams cause local, more moist conditions in some of the canyons. Dietrich (1965:22-23) also presents a good discussion of the effect of surface water:

> The U.S. Weather Bureau collects temperature data from a uniform height above the surface site selected to have data representative of large areas. These data accurately reflect the macroclimate, the climate above a thin boundary layer of air near the surface. The microclimate, the climate within the boundary layer a few inches to a few feet thick, is highly variable.
>
> Where the macroclimate is near the borderline separating steppe and desert climates, the effects of factors that modify the microclimate are dramatic. Surface attitude and texture are two important factors that affect surface temperature, and therefore the microclimate. South-facing slopes, more nearly normal to the sun's rays than north-facing slopes, or the floors of narrow-walled canyons, receive more abundant energy per unit area and are a little hotter and dryer. Soil on an open surface is hotter and drier than the soil in pockets between large boulders because the boulders shield the small pockets from direct solar radiation during part of the day. Because of these small differences, grass grows on north-facing or boulder-strewn surfaces at elevations where south-facing or open surfaces are barren. A tank, a spring, or flowing stream modifies the climate in a small area. Evaporation lowers the air temperature and increases the humidity in the immediate vicinity of the water.

These microclimate effects are particularly important in Fresno and Chorro Canyons and in Arroyos Primero and Segundo.

Although it is not clear what his source of data is, Corry 1972:3) makes the following statements about the climate in the Solitario:

> Rainfall in the area averages about 40 centimeters. Most of the rainfall occurs in the summer in the form of violent thunderstorms occasionally accompanied by high winds. Summer temperatures often exceed 40°C. but nights are normally cool and breezy. The humidity is fairly low. The peaks in the area occasionally receive some light snow in the winter, and the annual mean temperature is about 16°C.

GEOLOGIC HISTORY

Introduction

In this report we are concerned primarily with the most recent geologic history of the area, since Fresno Canyon has been incised fairly recently as a secondary result of the downcutting of the Rio Grande. A very old and complex history of geologic events can be read from the rocks exposed in the center of the Solitario. This history involves the accumulation of a thick sequence of old marine sedimentary rocks which were then complexly faulted and folded into what was probably a lofty mountain range at the close of Paleozoic time. These events are described in more detail in the companion report on the Solitario (Deal 1976a). The mountains were severely eroded, exposing their roots, before submergence beneath the Cretaceous seas (approximately 140 million years ago). In early Cretaceous time a sequence of limestone units was deposited. These are now exposed in the massive limestone cliffs that occur around the rim of the Solitario, along the Terlingua Monocline, and in Santa Elena Canyon and the other major canyons in Big Bend National Park. Overlying these massive limestones is a sequence of alternating hard and soft limestone beds of Upper Cretaceous age. These are the light-colored, flaggy units that extend from Fresno Canyon south of the Solitario through Terlingua and are the host rocks for most of the mercury ore deposits in the area.

A complex sequence of volcanic events then occurred with volcanic ash and lava deposits accumulating throughout the area from several sources. One source is the Bofecillos Volcano, which erupted from vents approximately 20 km (12 miles) northwest of the study area. Volcanic material from the Bofecillos vents interfingered with other volcanic material ejected from vents to the east in Big Bend National Park, to the north in the Davis Mountains, to the west from the vicinity of the Chinati Mountains, and to

Table 2 — Mean annual precipitation and geographic data, 27 stations in Trans Pecos Texas. (from Dietrich 1965: Table 3)

STATION					PRECIPITATION	
Name	Symbol *	Location		Elevation (ft. above MSL)	Record period **	Mean annual (inches)
		Lat.	Long.			
International Boundary and Water Commission						
American Dam	1	31°47'	106°32'	3,730	1938-61	7.49
Fabens-Guadalupe Bridge	2	31°26'	106°08'	3,610	1940-61	7.12
Fort Quitman	3	31°06'	105°36'	3,430	†1937-61	8.00
Adobes	4	29°46'	104°34'	2,550	1950-61	8.60
Presidio	5	29°34'	104°23'	2,550	1950-61	6.21
Quebec Ranch	6	30°31'	104°24'	4,600	1949-61	11.28
Bloys Camp	7	30°33'	104°07'	5,650	†1941-61	19.11
Kerr Mitchell Ranch	8	30°13'	104°00'	4,450	†1941-61	11.71
Loma Vista Ranch	9	30°13'	103°48'	5,450	†1941-61	12.01
H. T. Fletcher Ranch	10	30°12'	104°16'	5,100	†1939-61	14.49
Sauz Ranch	11	30°10'	104°12'	4,880	1940-61	13.68
A. L. Baugh Ranch	12	29°52'	104°02'	3,820	1942-61	10.16
H. M. Greenwood	13	29°48'	104°13'	4,000	1941-61	12.54
O2 Ranch	14	29°51'	103°45'	3,780	†1914-61	12.76
Johnson Ranch	15	29°01'	103°23'	2,050	†1933-61	7.54
Persimmon Gap Ranger Station	16	29°40'	103°10'	2,900	†1948-61	8.21
Steve Stumberg Ranch	17	30°11'	102°53'	4,300	†1943-61	12.52
Arvin and Harkins Header	18	30°27'	102°26'	3,400	1949-61	13.02
Arvin and Harkins Headquarters	19	30°27'	102°20'	2,930	1949-61	11.77
U.S. Weather Bureau						
El Paso	E	31°48'	106°24'	3,918	WBN	7.89
Van Horn	V	31°02'	104°51'	4,050	1939-63	9.52
Presidio	P	29°33'	104°24'	2,582	WBN	8.31
Mt. Locke	L	30°22'	104°00'	6,790	1945-63	18.72
Balmorhea	B	31°00'	103°41'	3,225	WBN	12.68
Alpine	A	30°22'	103°39'	4,433	WBN	15.42
Chisos Basin	C	29°16'	103°18'	5,300	1949-63	15.19
Fort Stockton	S	30°52'	102°55'	2,995	†1931-60	16.45

*Station identification on map (Fig. 2) and diagram (Fig. 3)
**WBN: Weather bureau normal for 1931-1960.
†: Some records missing.
Data sources. — International Boundary and Water Commission stations (I.B.C, 1961).
U.S. Weather Bureau stations: normals (WBN) from U.S. Weather Bureau (1962, p. 4); other means calculated from data in the office of the State Climatologist, Robert B. Mueller Airport, Austin, Texas.

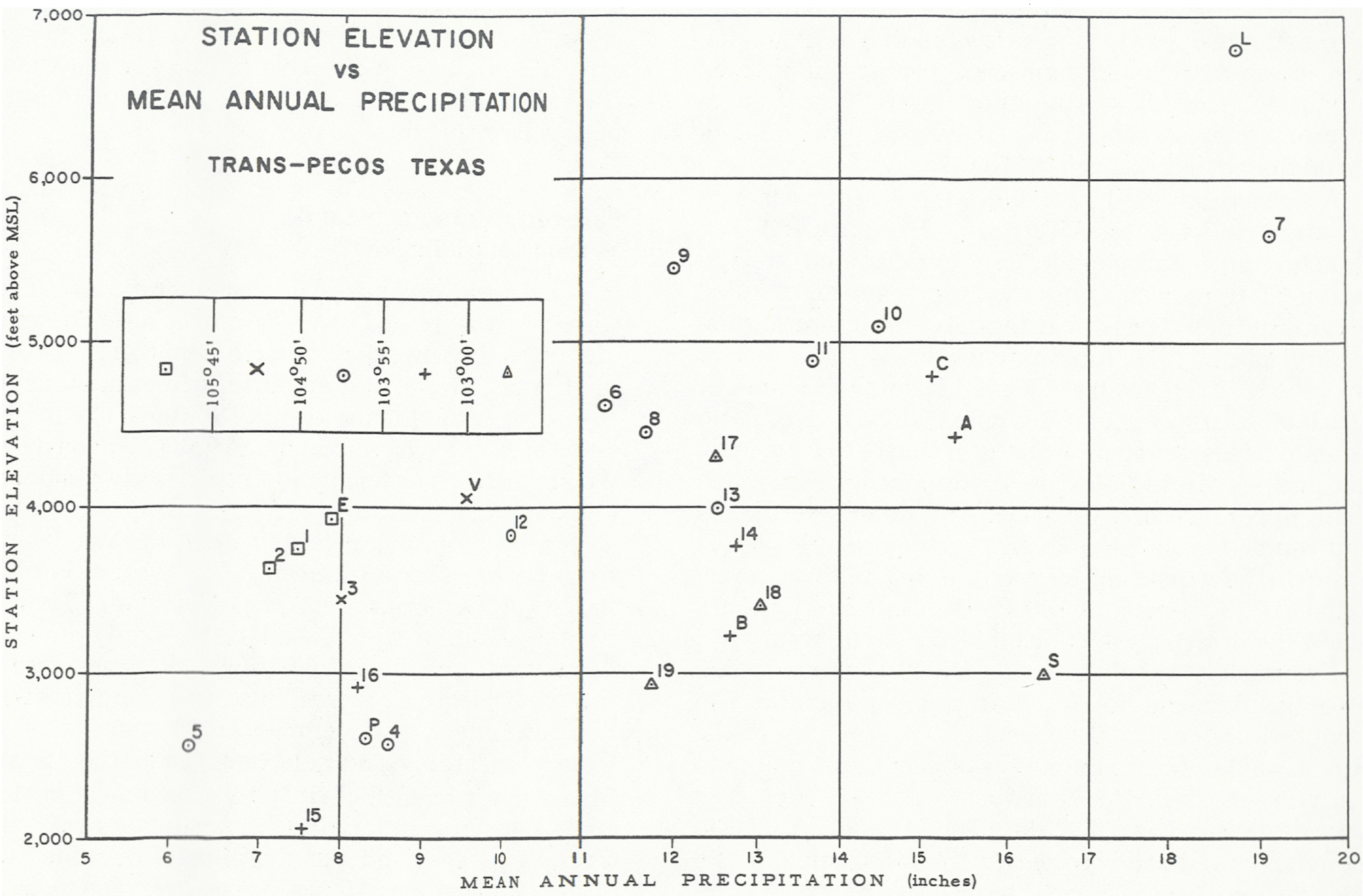

FIGURE 4

Station elevation versus mean annual precipitation at 27 stations in Trans Pecos Texas.
(From Dietrich 1965: Fig. 5)

the south, in Mexico. The details of the volcanic stratigraphy are described in the companion volume on the Bofecillos Mountains (Deal 1976b).

At the same time as volcanic materials were being erupted, complex block faulting occurred in this area. Vertical displacements along the faults continued long after volcanic activity ceased, and a landscape typical of the southwestern desert Basin and Range physiographic province was developed. The characteristic Basin and Range landscape consists of isolated mountain ranges surrounding desert basins with internal drainage (bolsons)—they have no outlet or through-flowing drainage to the sea.

A general uplift of western North America occurred in the late Tertiary. The ancestral Rio Conchos and Rio Grande, fed by increased precipitation in their now more-elevated headwaters, filled previously dry basins near their headwaters with temporary lakes. (The Rio Conchos heads southwest of the study area in the Sierra Madre Occidental of Mexico, southwest of Chihuahua City, and the Rio Grande heads in the mountains of northern New Mexico and southern Colorado.) When those rivers filled their upper basins with lakes, the water overflowed and spilled downstream into progressively lower basins. The upstream lake basins began to be excavated by the ancestral Rio Grande and Rio Conchos when the drainage overflowed into a lower basin.

Eventually one of the two ancestral rivers spilled into the Presidio bolson. It is possible that the Rio Conchos arrived in the Presidio area long before the Rio Grande (see companion volume on Colorado Canyon of the Rio Grande by Deal 1976c). The ancestral drainage of the Rio Grande (or Rio Conchos) probably proceeded in this fashion to fill the Presidio bolson briefly with a lake and then overflowed across the divide southeast of Redford, now the location of Colorado Canyon, into a lower basin. In this way the ancestral river probably worked its way eastward until it finally overflowed into the headwaters of some tributary of the ancestral lower Rio Grande, somewhere east of what is now Big Bend National Park. At that time the ancestral Rio Grande (or Rio Conchos) established an integrated drainage to the Gulf of Mexico, and the upstream segments of the river south of the Solitario began to downcut more rapidly.

Tributaries of the Rio Grande, such as Fresno Creek, began to downcut as the main canyons of the Rio Grande were incised. With increased downcutting along the Rio Grande, Fresno Creek began to incise Fresno Canyon and its tributaries more rapidly, accelerating the dissection of both the Solitario Dome and the Bofecillos Volcano.

Both Arroyo Primero and Arroyo Segundo, as well as their tributaries, contain numerous perennial springs and seeps. The hydrologic conditions that result in these springs and seeps are described in more detail in the companion volume on the Bofecillos Mountains (Deal 1976b). Most of the water that occurs intermittently along the course of Fresno Creek from the Smith Ranch ruins southward comes directly or indirectly from the springs and seeps that issue from the Bofecillos volcanic units on the western side of the canyon. This is true for the water at the Smith Ranch, Fresno Falls, and Trough Springs below Fresno Falls.

Paleozoic Stratigraphy and Mountain Building

The older rocks known to underlie the Fresno Canyon area are of Lower Paleozoic age. These rocks are exposed within the Solitario Dome just to the east of Fresno Canyon and are described in more detail in the companion volume on the Solitario (Deal 1976a) and in the works of Herrin (1958), Wilson (1954), West Texas Geologic Society Field Guidebooks (1965, 1972), and Corry (1972).

Briefly, from oldest to youngest, the Paleozoic section consists of the following: The Dagger Flat Sandstone of Cambrian age; the Marathon Formation (black siliceous shale, sandstone, sandy limestone, dark chert, and blue limestone), the Fort Peña Formation (limestone, sandy limestones, and cherts), the Woods Hollow Shale (fine-grained shale with some flaggy sandstones and siltstones), and the Maravillas Chert (black bedded chert with some limestone lenses and some intraformational conglomerates), all of Ordovician age; and the Caballos Novaculite (white chert) of Devonian-Mississippian age. The two chert units (the Maravillas Chert and the Caballos Novaculite) are prominent ridge-formers within the Solitario. The total thickness of the Paleozoic section in the Solitario is about 2600 m.

A major series of mountain-building events followed the deposition of the Paleozoic rocks in Late Pennsylvania-Early Permian time (Flawn and others 1961:188; Deal 1976a). These events were part of what is called the Ouachita Orogeny, a major and continuous band of folding that extended over much of the southern United States, comparable in age and type to the Appalachian Mountain structures of the eastern United States. The axis of the Ouachita fold belt in the Solitario-Marathon region extends northeast to southwest with thrusting and compression from the southeast to the northwest. These intensely folded, distorted, and faulted rocks certainly underlie Fresno Canyon.

Herrin (1958:73) found some indirect evidence indicating that some rocks of Permian age may have been deposited in this area. He found Permian fossils in small boulders of limestone included in a tuffaceous conglomerate within the Tertiary volcanic sequence exposed in the southern part of the Solitario, but if Permian rocks were deposited in the vicinity of the study area, they were removed by erosion prior to the deposition of the Cretaceous limestones. Everywhere in southern Brewster and Presidio Counties the Cretaceous rocks lie directly on the intensely deformed Paleozoic sediments.

Cretaceous Stratigraphy and Mountain Building

Following the Ouachita mountain-building period, Trans-Pecos Texas experienced a considerable time of erosion. The area was above sea level and erosion reduced what must have been a magnificent mountain range to a nearly flat, relatively featureless plain. In early Cretaceous time (about 145 million years ago) the southeastern Presidio County area was submerged once again beneath ocean waters and a sequence of massive limestones was deposited in a northward extension of the Mexican Geosyncline.

The Cretaceous rocks are described in more detail in Appendix 1 and can conveniently be considered as consisting of two major subdivisions. The older Lower Cretaceous rocks are predominantly massive limestones that form the impressive cliffs exposed in a number of the canyons in Big Bend National Park (Santa Elena, Mariscal, and Boquillas Canyons) and in the steeply-dipping rim of the Solitario. Overlying these are a sequence of alternating hard and soft units that include the uppermost Lower Cretaceous rocks (the Del Rio Clay and Buda Limestone) and the Upper Cretaceous rocks (Boquillas, Penn, and Aguja Formations).

Within the Solitario the Cretaceous section begins with a basal conglomerate (the Shutup Conglomerate). All the rest of the older Lower Cretaceous rocks are limestones and are beautifully exposed in the rim escarpement around the Solitario, a portion of which forms the northeastern wall of Fresno Canyon. Herrin (1958) divided the Lower Cretaceous into seven formations. His stratigraphic names were informal and later work by Maxwell and others (1967) has formally named the rock units in Big Bend National Park. Smith (1970) further defined the Lower Cretaceous stratigraphy of northern Coahuila. In his work on the Solitario, Corry (1972) correlated the work of Maxwell and others (1967) and Smith (1970) with Herrin's (1958) mapping and applied the current terminology to rocks exposed around the Solitario. A correlation of the Lower Cretaceous rocks in the Solitario, Big Bend National Park, southwest Texas, and central Texas is shown in Table 3. A correlation of the Lower Cretaceous fossils from the Solitario, Big Bend National Park, and northern Coahuila, Mexico, is shown in Table 4.

The Lower Cretaceous units are not really exposed in Fresno Canyon itself, but if a visitor walks up through any of the shutups that disect the Solitario (Righthand Shutup, Los Portales Shutup, or Lower Shutup), he will pass through the entire older Lower Cretaceous section starting with the youngest and progressing to the oldest, the Shutup Conglomerate. Turning around and heading back down toward Fresno Canyon, he will pass through the sequence of very resistant to moderately resistant limestones which overlie the conglomerate in proper order, from oldest to youngest: Yucca Formation, Glen Rose Formation, Telephone Canyon Formation, Del Carmen Limestone, Sue Peaks Formation, and Santa Elena Limestone. The three most massive cliff-forming units in this sequence are the Glen Rose Formation, Del Carmen Limestone, and Santa Elena Limestone. The Telephone Canyon Formation and Sue Peaks Formation are less resistant to erosion and tend to form breaks in the sheer cliffs of the shutups. The uppermost massive limestone, the Santa Elena Limestone, is the unit that forms most of the prominent cliffs along the western flank of the Solitario. The large shelters at Los Portales (Fig. 5) are formed

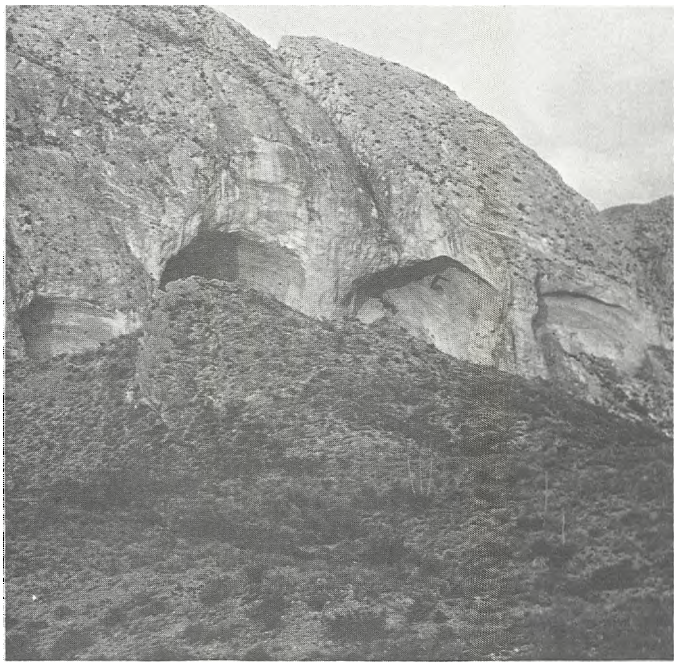

FIGURE 5

Los Portales. Shelters eroded in the Santa Elena Limestone. Photo by Reagan Bradshaw

Table 3 – Regional Correlation Table for Cretaceous Formations (after Maxwell and others 1967)

System	Series	Stage		Group	Solitario	Big Bend National Park Area	Southwest Texas	Central Texas
Cretaceous	Gulfian	Turonian		Terlingua	Boquillas Formation	Boquillas Formation	Eagle Ford Formation	Eagle Ford Formation
	Comanchean	Cenomanian		Washita	Disconformity Buda Limestone Del Rio Clay	Disconformity Buda Limestone Del Rio Clay	Disconformity Buda Limestone Del Rio Clay	Pepper Formation Buda Limestone Grayson Formation
		Albian	Upper / Middle		Santa Elena Limestone Sue Peaks Formation	Santa Elena Limestone Sue Peaks Formation	Georgetown Limestone Duck Creek Formation Kiamichi Formation	Georgetown Limestone Kiamichi Formation
			Middle	Fredricks-burg	Del Carmen Limestone Telephone Canyon Formation	Del Carmen Limestone Telephone Canyon Formation Maxon Sandstone	Fredricksburg Formation	Edwards Limestone Comanche Peak Limestone Walnut Clay Paluxy
			Lower	Trinity	Glen Rose Formation	Glen Rose Formation	Glen Rose Formation	Glen Rose Formation
		Aptian			Yucca Formation Shutup Conglomerate			

Table 4 — Lower Cretaceous Formation Fossil Correlation — Comanchean Series
(from Corry 1972: 80-83)

Stage	Formation	Solitario (Herrin 1958)	Big Bend National Park (Maxwell and others 1967)	Northern Coahuila, Mexico (Smith 1970)
Upper Albian	Santa Elena Limestone (Georgetown equivalent)	*Enallaster texanus* (Roemer) *Gryphaea washitaenis* (Hill) *Gryphaea* sp. + *Hamites* *Holaster simplex* (Shumard) *Kingena wacoenis* (Roemer) *Pecten (Neithea) bellula* (?) Cragin *Pecten (Neithea) texanus* (Roemer) *Turrilites brazoensis* (Roemer)	*Eoradiolites* cf. *E. quadratus* *Gryphaea* sp. +	*Toucasia* sp. *Gryphaea* sp.+ *Chondrodonta* sp.
Middle Albian	Sue Peaks Formation		See Maxwell and others 1967: p. 44, for listing	Pelecypoda-19 species Gastropoda-9 species Echinodermata-3 species Ammonidea-3 species (see Smith 1970: p. 41-42 for complete listing)
	Del Carmen Limestone	*Gryphaea mucronata** (Gabb) *Exogyra texana** (Roemer) *Lima (Mantellum) wacoensis* (Roemer) *Nerinea* sp. + *Pecten* sp. *Pleurotomaria* (?) + *Turrilites brazoensis* (Roemer)	*Exogyra texana* (Roemer) *Protocardia texana* (Roemer) *Pholadomya sanctisabae* (Roemer) *Aporrhais tarrantensis* (Stanton) *Eoradiolites* cf. *E. dayidson* (Hill) *Gryphea* sp. *Tapes* sp. *Cardium* sp. *Protocardium* sp. *Turritella* sp. *Tylostoma* sp. *Radiolites* sp.	*Toucasia* sp. *Monopleura* sp. *Gryphaea* sp.
	Telephone Canyon Formation		*Gryphaea mucronata** (Gabb) *Exogyra texana** (Roemer) *Aporrhais tarrentensis* (Stanton) *Tapes chihuahuensis* (Bose) *Metengonoceras* cf. *M. ambiguum* (Hyatt) *Neithea irregularis* (Bose) *Cardium* sp. *Protocardium* sp. *Tylostoma* sp. *Enallaster* sp. *Gyrphaea* sp. *Engonoceras* sp.	*Gryphaea mucronata** (Gabb) *Exogyra texana** (Roemer) *Ostrea* sp. *Pecten subalpinus* (Bose) *P. occidentalis* (Conrad) *Cyprimeria texana* *Cardium* cf. *C. congestum* (Bose) *Lima* sp. *Pteria pedernalis* (Roemer) *Tapes aldamensis* (Bose) *T. quadalupae* (Bose) *Anchura* (?) +

Stage	Formation	Solitario (Herrin, 1958)	Big Bend National Park (Maxwell and others, 1967)	Northern Coahuila, Mexico (Smith, 1970)
			Gyrodes sp. *Amauropsis* sp. *Cyprimeria* sp. *Trigonia* sp. *Phyoadomya* sp. *Turritella* sp. *Nerinea* sp.	*Astarte* (?) + *Pholadmya* sp. cf. *P. sanctisabae* (Roemer) *P. shattucki* (Bose) *Protocardia texana* (Conrad) *Cucullaea* sp. *Nucula* (?) sp. cf. *N. fortworthensis* (Perkins) *Tylostoma* sp. aff. *T. regina* (Cragin) *Turritella* sp. *Nerinea* (?) sp. + *Pleurotomaria* sp. + *Kingena* sp. *Phymosoma texana* (Roemer)
Lower to Middle Albian	Glen Rose Formation	*Exogyra quitmanensis** (Cragin) *E. texana* (Roemer) *Hemiaster comanchei* (Clark) *Pecten occidentalis* (Conrad) *Plicatula* sp. *Nerinea roemeri* (Whitney) *Salenia texana* (Credner) *Lima* (?) sp. *Lunatia* (?) sp. *Orbitolina texana** (Roemer) *Pecten* sp. *Protocardia* sp.	*Exogyra quitmanensis** (Cragin) *Exogyra texana** (Roemer) *Douvilleiceras* cf. *D. mammilatum* (Schlotheim) *Inoperna* aff. *I. concentriccostellata* (Roemer) *Orbitolina texana** (Roemer) *Porocystis globularis** (Giebel)	*Exogyra quitmanensis** (Cragin) *Cymatoceras* sp. *Parahopilites* n. sp. *Hypacanthoplites mayfieldensis* (Scott) *Hypacanthoplites* n. sp. *Gryphea mucronata* (Gabb) *Douvilleiceras* sp. cf. *D. spathi* (Scott) *Hemiaster* sp. *H. Comanchei** (Clark) *Kingena* (?) sp. *Tylostoma* sp. *Knemiceras* (?) sp. *Nerinea* sp. *Enallaster obliquatus* (Clark) *Porocystis globularis** (Giebel) *Homomya* sp. *Pecten* sp. *Gryphaea wardi* (Hill and Vaughan) *Arctica* n. sp. *Cardium* n. sp. *Tapes* n. sp. *Protocardia* n. sp. *Liopista* *Liopistha* spp. *Lucina* sp. *Cucullaea* n. sp. *Luathia* (?) *praegrandis* (Roemer) *Orbitolina texana** (Roemer)

* indicates correlation of both genus and species
+ indicates correlation of species only

in this unit, as are most of the cliffs and flatirons along the eastern side of Fresno Canyon. The Del Carmen Limestone holds up the summit of Fresno Peak itself (Fig. 1) and most of the highest rimrock that can be seen around the Solitario from Fresno Canyon.

Overlying the uppermost thick, massive limestone unit (Santa Elena Limestone) is the soft Del Rio Clay. The Del Rio is exposed in a number of places in the drainages along the eastern side of Fresno Creek at the base of the steeply westward-dipping cliffs of Santa Elena and is overlain by the resistant Buda Limestone, exposed extensively along the eastern side of Fresno Canyon (McKnight 1970: geologic map). The Buda is the most uniform and widespread Cretaceous unit in West Texas. It was originally described along Shoal Creek in Austin, Texas, and is nearly identical in appearance here in Presidio County. The Buda Limestone is about 21 m (70 ft) thick in Fresno Canyon and is a very massive, poorly-bedded, nodular, white limestone. It is prominently exposed in the bed of Fresno Creek in the vicinity of the Shelter Thrust, approximately 7.5 km (4.5 miles) north of the Smith Ranch ruins and for several kilometers north and south of that point along the eastern side of the creek. It normally forms small barriers, narrow steep canyons, and pouroffs where major tributary drainages cross the outcrop. This is especially true in the drainages in the vicinity of the Lower Shutup, east of the Smith Ranch ruins (Fig. 6).

The Buda Limestone is the youngest, uppermost member of the Lower Cretaceous (Comanche Series) rocks. Overlying the Buda are the younger Upper Cretaceous (Gulf Series) strata. From oldest to youngest the series includes the: Boquillas Formation (the classic "Boquillas flagstone" beds) composed of interbedded calcareous clay and thin-bedded clayey limestone, the lower part of which is mostly limestone with clay partings that cause it to break into thin flaggy plates, becoming mostly shale in the upper half of the formation; Penn Formation (gray clay weathering yellow to buff, containing clays with high shrink-swell properties and some gypsum); and Aguja Formation (interbedded gray to gray-green and brown sandstone and shale). Table 5 correlates the various names used by different workers in the Big Bend Region for these rocks.

The Boquillas Formation is exposed for several kilometers in the bed of Fresno Creek north of Arroyo Segundo, along the eastern side of the study area south of the Solitario Uplift, and in the drainages leading to the Lower Shutup. It is also exposed in the southeastern part of the study area and along Fresno Creek from the Wax Factory Laccolith north to the

FIGURE 6

Buda Limestone forming narrow canyon about 2 km west of the Lower Shutup. Fresno Peak, on the skyline, is composed of older, lower limestones of Cretaceous age. The Del Rio Clay is exposed between the outcrops of Buda Limestone and Fresno Peak. Photo by Dwight Deal

Solitario. The Boquillas Formation is also exposed more or less continuously along the county road from the Fresno and Whitroy mines to paved Ranch Road 170 near Lajitas. This unit is the main host rock for the mercury ore found in the Terlingua District.

Approximately 1.2 km of thick, flat-lying limestones were deposited on top of the intensely deformed and eroded Paleozoic rocks. Following their deposition, the main mountain-building episode of the North American Cordillera, known as the Laramide Orogeny, occurred. It is evidenced in Trans-Pecos Texas by the creation of folded uplifts and associated faulting. The Laramide mountain-building period began in Late Cretaceous time and continued into the early Tertiary. The Laramide mountain-building period was followed by a series of

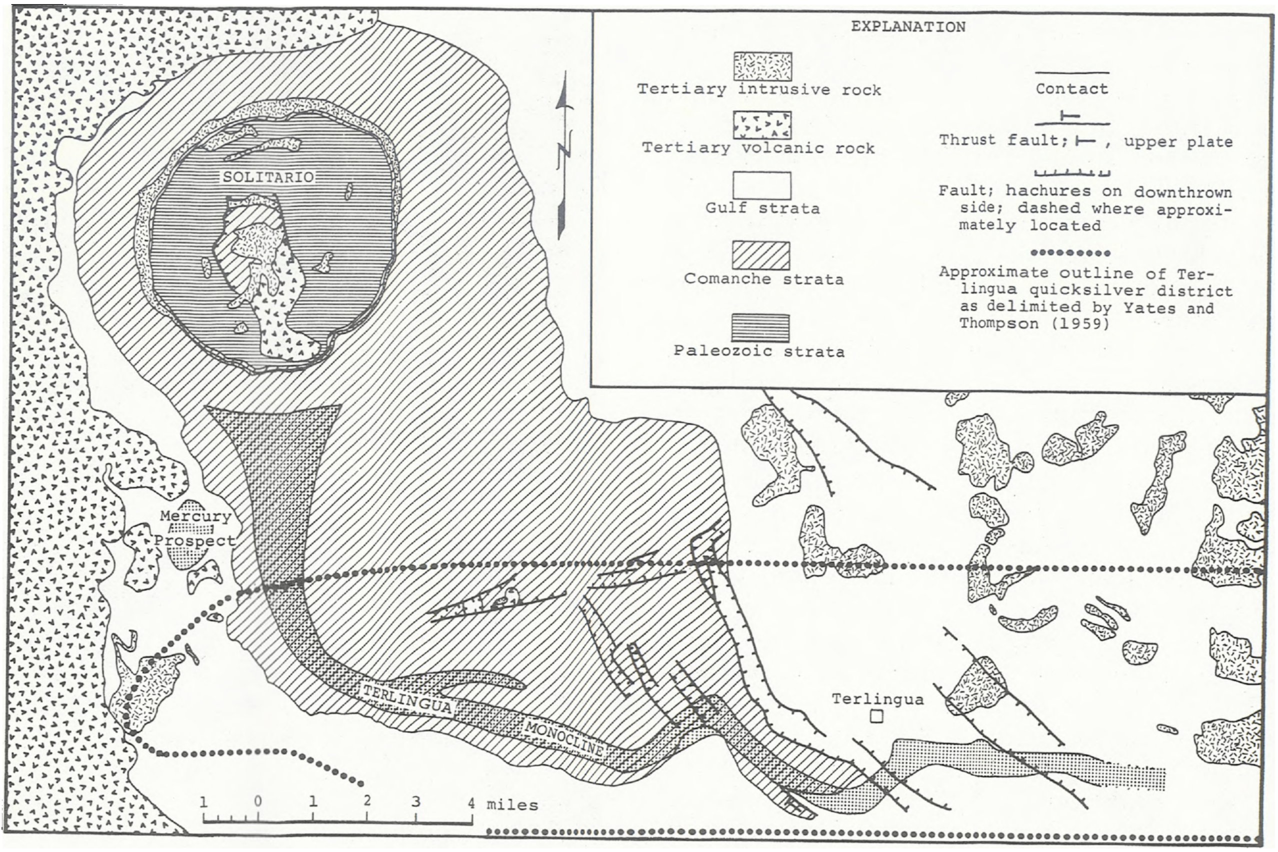

FIGURE 7

Generalized geologic map of Terlinqua-Solitario area, showing the mercury prospect on east side of the Bofecillos Mountain Area. Modified from Lonsdale (1950) and Yates and Thompson (1958) by McKnight (1968: Fig. 20)

igneous intrusions, in turn followed by a series of volcanic eruptions which buried the limestones beneath a sequence of volcanic ash deposits and lava flows.

The first evidence of volcanic activity in southeastern Presidio County was an intrusion of magma into the base of the Cretaceous limestone sequence in early to middle Tertiary (probably Eocene or Miocene) time (possibly 20 to 45 millions years ago; Fred McDowell, oral communication, March 1976). Then, as the orogeny progressed, the Solitario Dome was formed. After the doming of the Solitario and prior to the deposition of the Tertiary volcanic rocks in the area, the structure known as the Terlingua-Solitario Monocline (Maxwell and others 1967) was formed. This structure extends northwestward into the southeastern edge of the Fresno Canyon area, where the trend turns northward and merges with the Solitario structure (Fig. 7). The origin of this structure is discussed in more detail in Appendix 2.

Tertiary Volcanic Stratigraphy

Laramide mountain building led into a sequence of Tertiary volcanic events that affected most of southern and western United States and northern Mexico. The details of the volcanic stratigraphy of west Texas are extremely complicated; there are many individual beds that were erupted from a number of distinctly isolated volcanic centers. There were several major eruptive centers and many minor ones in the Big Bend area. Major centers include the Chisos Mountains in Big Bend National Park, Davis Mountains, Chinati Peak, and several south of the Rio Grande in Mexico. The Bofecillos Volcano was a relatively small and localized eruptive center, located approximately 16 km (10 miles) northwest of the center of the Fresno Canyon study area, and active toward the close of the main volcanic period.

The Tertiary volcanic sequence is described in much greater detail in the companion volume on the Bofecillos Mountains (Deal, 1976b). Briefly, from oldest to youngest, the Tertiary units consist of the following formations: Jeff Conglomerate, Chisos Formation, Mitchell Mesa Tuff, Fresno Formation, Santana Tuff, and Rawls Formation.

Jeff Conglomerate

Prior to the eruption of the main volcanic phase, a

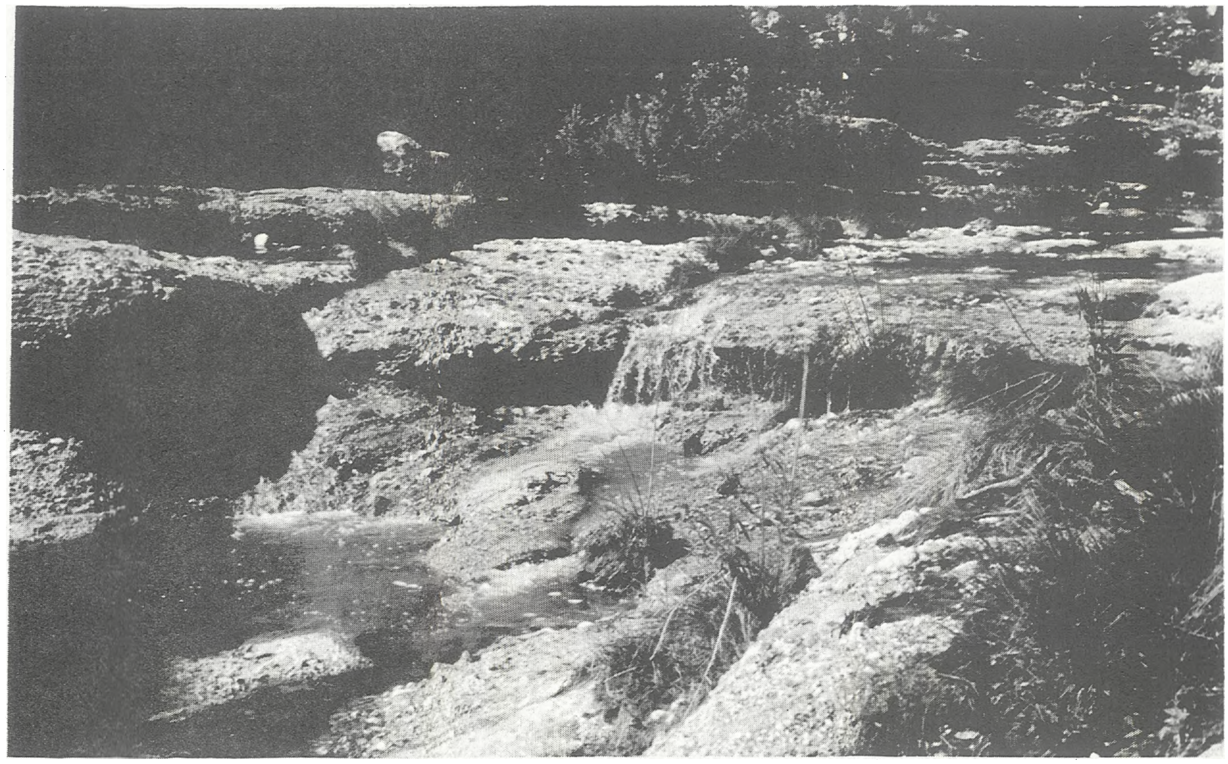

FIGURE 8

Outcrops of Jeff Conglomerate forms the lower cascade at Fresno Falls. Photo by Dwight Deal

sedimentary conglomerate consisting mostly of well-rounded cobbles or boulders of limestone was deposited in the Fresno Canyon area. In a few places in Fresno Canyon it contains weathered, rounded, vesicular fragments of igneous rocks up to 15 cm in diameter (McKnight 1968:25-31). In some locations the formation also contains scattered, angular pebble- to boulder-sized fragments of petrified wood. I observed an angular fragment of black chert from the Maravillas Formation in the Jeff Conglomerate in an outcrop in Fresno Canyon in June, 1975. The dominant limestone boulders and pebbles look like the Cretaceous Del Carmen, Santa Elena, and Buda Limestone that are exposed on the Terlingua-Solitario Monocline and in the Solitario, but they are so uniformly well-rounded they may well have been transported from some distant source. Some problems with the name "Jeff" are discussed in detail elsewhere (McKnight 1968:25-31; Deal 1976b: Appendix 1). In this report I continue to use the name "Jeff Conglomerate" for this unit.

The Jeff Conglomerate is a resistant unit and where it is exposed in the floor of Fresno Canyon and its tributaries it commonly forms a scenic, light-colored ledge or ledges with pools, cascades, swimming holes, and a local abundance of surface water through the year (Fig. 8). The Jeff Conglomerate is well-cemented and relatively impermeable to groundwater flow. Ground water present in the sandy and gravelly arroyo beds is, therefore, forced to the surface by the Jeff outcrops.

The two most scenic outcrops of the Jeff occur in Fresno Canyon at Fresno Falls (Figs. 9 and 10) and in Arroyo Segundo between the base of Mexicano Falls and Fresno Creek (Fig. 11). Fresno Falls is located in the floor of Fresno Canyon immediately upstream

FIGURE 9

Ledge of Jeff Conglomerate at Fresno Falls. Photo by Dwight Deal

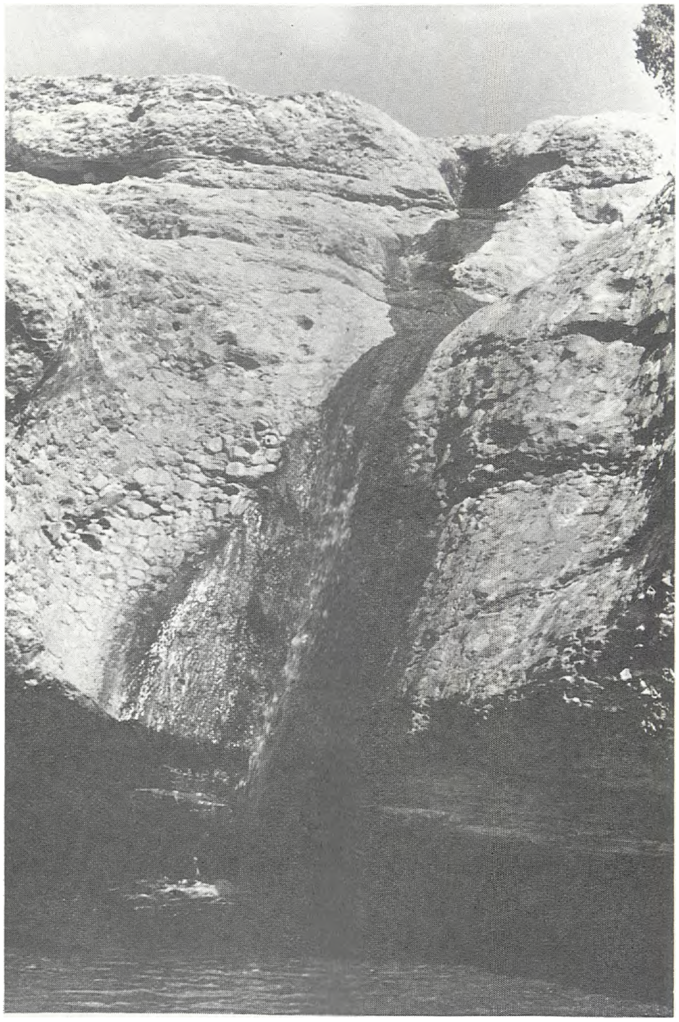

FIGURE 10

Fresno Falls.
Photo by Reagan Bradshaw

from the mouth of arroyo Primero, approximately 3 km (2 miles) below the Smith Ranch ruins and about 4 km (2.5 miles) upstream from the place where the road from the Whitroy and Fresno mines enters Fresno Creek at the Wax Factory Laccolith. All the water flowing in Fresno Creek passes over two cascades, the upstream one containing about a one-meter high waterfall (Fresno Falls). The short stretch of Fresno Canyon between Fresno Falls and the mouth of Arroyo Primero is a high gradient area normally choked with a jumble of boulders and flood debris. Vehicular access into the Fresno Canyon area from the south often terminates at this point. The Jeff outcrop in Arroyo Segundo (Fig. 12) is similar, but usually forces less water to the surface as it is fed only by springs in Arroyo Segundo. It also forms a barrier across the canyon floor, and, even with a 4-wheel-drive vehicle, access is terminated a short distance downstream from the outcrop of Jeff Conglomerate.

Chisos Formation

The volcanic rocks that overlie the Jeff Conglomerate in Fresno Canyon are the dominantly light-colored, soft, volcanic ash deposits of the Chisos Formation. These strata are mostly composed of volcanic ash falls (tuff) and associated stream deposits (conglomerates and sandstones), mud flows, lake deposits (non-marine limestone), and wind-blown ash, dust, and sand. A few lava flows, probably erupted from vents southeast of Fresno Canyon in the vicinity of what is now Big Bend National Park, also are contained within the Chisos Formation. Because Fresno Canyon is some distance from the source of the Chisos, the beds in the study area are predominantly composed of ash falls and associated sedimentary deposits. Few of the lava flows were extensive enough to reach what is now the vicinity of Fresno Canyon.

Low, easily-eroded white cliffs are prominent along the bed of Fresno Creek throughout the southern half of the study area. They extend southward from the vicinity of Los Portales, the large shelters on the west flank of the Solitario, past the mouth of Arroyo Segundo, and past the Smith Ranch ruins to the Wax Factory Laccolith. This unit is particularly well exposed in Arroyo Segundo between the Jeff Conglomerate outcrops mentioned previously and the base of Mexicano Falls. Along most of the exposure, however, the soft slope-forming Chisos Formation is mantled with a veneer of rock fragments and debris from the cliffs and slopes above.

Of particular interest are the outcrops of non-marine limestone in Fresno Canyon southeast of the Smith Ranch ruins, about 3 km (2 miles) southeast of Rincon Mountain. At this location a small breached dome exposes the lower 21 m (70 ft) of the Chisos Formation. The limestone beds form white, cream, or gray-mottled limestone ledges within a sequence of tuff, sandstone, and mudrock. The lower of the two beds reaches thicknesses of up to 1.2 m (4 ft) and occurs immediately above 6 m (20 ft) of Jeff Conglomerate. The upper bed reaches thicknesses of up to 7.5 m (25 ft), with the base about 9 m (30 ft) above the top of the Jeff. McKnight (1968:38) describes the presence of broken calcite shell fragments, some recognizable as gastropods (snails), as being abundant in some zones. He concludes that these limestone beds were probably deposited in intermittent ponds or small lakes.

A number of flow and ash units have been described within the Chisos Formation (Maxwell and others 1967; Deal 1976b; Appendix 1), two of which are exposed in Fresno Canyon. One of these is the Mule Ear Spring Tuff which represents what is probably a single ash flow of nonwelded to moderately-welded tuff (see discussion of Mitchell Mesa Tuff for

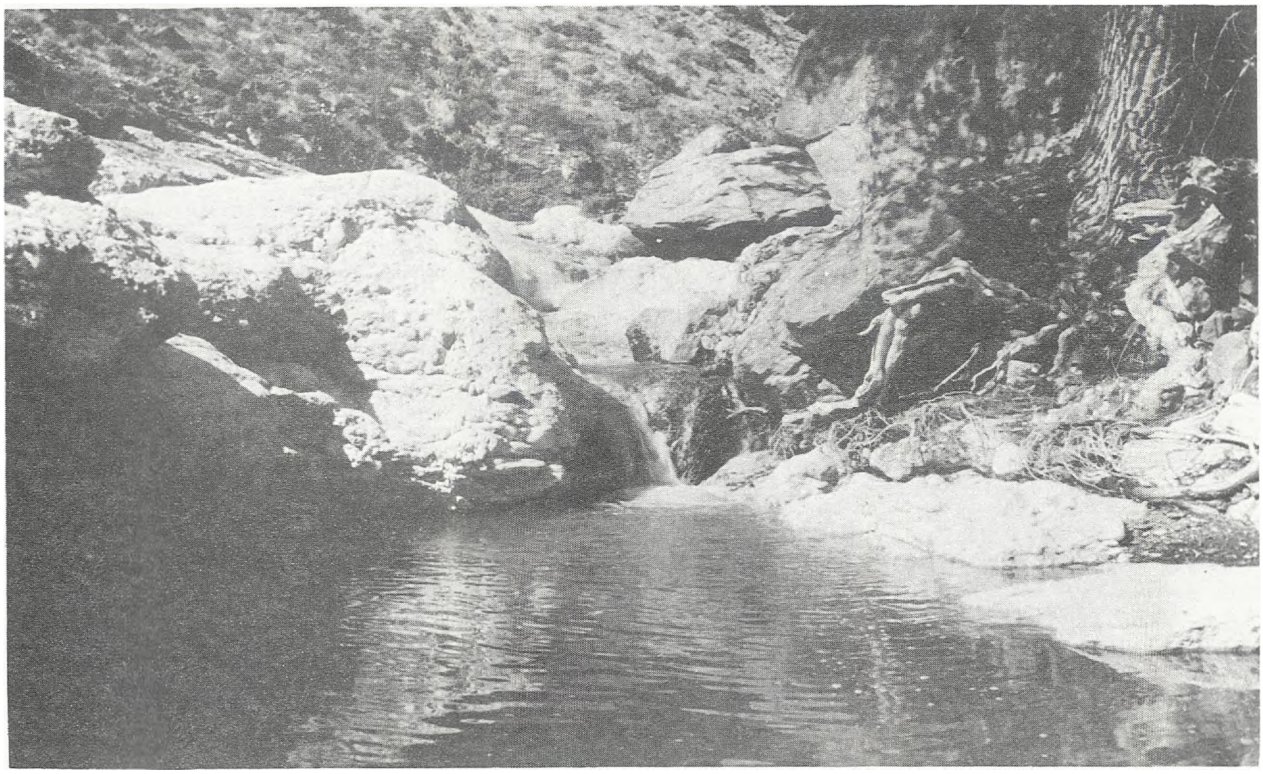

FIGURE 11
Eight-foot deep pool below a ledge of Jeff Conglomerate in Arroyo Segundo.
Photo by Dwight Deal

FIGURE 12
Jeff Conglomerate outcrops in Arroyo Segundo forces ground-water to the surface. Fresno Peak in background.
Photo by Dwight Deal

an explanation of a "welded tuff"). It reaches thickness of up to 12 m (40 ft) in Fresno Canyon (McKnight 1968:45).

The only lava flow that was extensive enough to reach the Fresno Canyon area occurs in the upper part of the Chisos Formation. This is the Tule Mountain trachyandesite porphyry. McKnight (1968:55) thinks that this unit probably originated as a single lava flow and describes it as follows:

> A poorly defined orange-weathering scoriaceous basal breccia less than a foot thick is overlain by a vesicular zone a few feet thick. It grades upward to green, brown, or black nonvesicular, altered, porphyritic, intersertal, celadonitic aegirine-augite trachyandesite typical of most of the unit. The trachyandesite, particularly the upper half, exhibits a marked swirled flow structure; it tends to split along the flow foliation producing abundant spalls, which litter the slopes below the outcrop. The spalls are mostly four inches to two feet across, but some are as large as slump blocks. The upper 10 feet is vesicular or scoriaceous and weathers orange to red-brown.

The Tule Mountain Member is present as a prominent cliff beneath the cliff of Mitchell Mesa Tuff in the southern part of the study area. It is exposed in the walls of Fresno Canyon from the general vicinity of the mouth of Arroyo Primero southward all the way to the Rio Grande. It thins from southeast to northwest, pinching out in the vicinity of Fresno Falls and absent in Fresno Canyon north of that point.

The stratigraphy and age of the Chisos Formation is discussed in more detail by McKnight (1968:31-56) and Deal (1976b:Appendix 1).

Mitchell Mesa Tuff

The Mitchell Mesa Tuff overlies the Chisos beds. It is a distinctive and interesting rock unit which usually forms a very resistant layer that the non-geologist would probably mistake for a solidified lava flow. It is not, however, an ancient lava flow but originated from what was either a single, violent eruption or a series of closely related violent eruptions of large quantities of very hot volcanic ash. The particles of ash were so hot when they came to rest that in most places they fused together and "welded" themselves into this very hard and resistant unit. A deposit of this type is referred to as an "ignimbrite" or "welded tuff" and is about the closest thing to "instant rock" that one can find in the geologic record. Most sedimentary rock units characteristically were deposited over a span of millions of years. In contrast, ignimbrites usually record a single event or a series of events very closely spaced in time. The Mule Ear Spring Tuff, in the underlying Chisos Formation, and the Santana Tuff, overlying the Fresno Formation, are similar deposits. A more detailed description of the eruptive mechanism responsible for these unusual units is given in the companion volume on the Bofecillos Mountains (Deal 1976b).

The top of the Mitchell Mesa Tuff is one of the most useful horizons for the stratigraphic correlation of the volcanic rocks in the Big Bend region of Texas. Not only does it form a hard, resistant, and distinctive unit, it covers an immense area. Known occurrences extend from the area of Big Bend Park northward to the Davis Mountains (north of Alpine) and westward (where it is called the Brite Ignimbrite) to the rimrock country south of Van Horn. Dietrich (1965) estimated a minimum areal extent of four million hectares (2500 square miles) in the United States and Haenggi (1966) estimates a minimum of an additional one million hectares (700 square miles) in Mexico west of Presidio.

McKnight (1968:57) describes the Mitchell Mesa as a cliff-forming ash-flow tuff that lies either directly above the Tule Mountain Member of the Chisos Formation or above as much as 6 m (20 ft) of Chisos Tuff. The Mitchell Mesa usually ranges between 6 and 11 m (20 and 35 ft) in thickness with a maximum thickness of about 15 m (50 ft) in the Bofecillos Mountains area, which includes Fresno Canyon. The Mitchell Mesa Tuff thins against the flank of the Solitario Uplift, indicating that the uplift was high at the time the tuff was deposited. Thin or absent units may result either from non-deposition or from subsequent erosion after deposition. The very resistant nature of this unit indicates that the thinning of the Mitchell Mesa Tuff in this area probably resulted from non-deposition.

The Mitchell Mesa Tuff also is absent from the section in the vicinity of the Wax Factory Laccolith in the southern part of the Fresno Canyon study area, indicating that a topographic high also existed there. A lens of Mitchell Mesa Tuff is present in the walls of Fresno Canyon between the Wax Factory Laccolith and the Smith Ranch ruins. It is well exposed along and slightly above the road that runs from Fresno Canyon to the Madrid Ranch ruins in Arroyo Primero, forming the light-colored resistant ledge several feet thick at the top of the very steep hill where the road ascends the western wall of Fresno Canyon, just prior to descending into Arroyo Primero. This unit forms a fairly obvious light-colored ledge in the walls of Fresno Canyon and can easily be traced north and south. The wedge-edge of this unit is obvious from the canyon floor.

Fresno Formation

The Fresno Formation consists of a sequence of ash falls, sandstones, conglomerates, ash-flow tuffs, volcanic mud flows, breccias, some wind-blown material, and a number of lava flows. McKnight (1968, 1970) has mapped nine units in the Fresno Formation which are described in more detail in a companion volume on the Bofecillos Mountains (Deal 1976b). In the Fresno Canyon study area, the Fresno Formation contains mostly volcanic ash with some interbedded lava flows. McKnight (1970: geologic map) shows four of his nine units present: undifferentiated tuff (map symbol Tf), and three included lava flow, a mafic trachyandesite (Tfa), a latite porphyry (Tflp), and a sodic rhyolite (Tfsr).

Fresno Formation, Undifferentiated (Tf).—The lower part of the Fresno Formation, as exposed in Fresno Canyon, is a light-colored, easily-eroded, slope-forming sequence of ash-fall tuff, wind-blown tuff, tuffaceous conglomerate, and conglomeratic sandstone. Superficially it is very similar to the underlying Chisos tuffs, and, where the Mitchell Mesa Tuff is absent, the upper Chisos and lower Fresno intergrade. The lower beds in the Fresno Formation typically have crossbed sets with large-scale sets, often one and one-half meters or more thick, that may occur in zones up to 30 m thick. Similar beds occur in the upper part of the Chisos Formation, but in general there is a gradual upward transition from ash-fall tuff in the upper Chisos and lower Fresno Formation to wind-deposited sandy tuff in the middle and upper Fresno Formation. McKnight

(1968:65) feels this probably reflects a more rapid deposition of volcanic ash in Fresno time that smothered or poisoned soil-holding vegetation, allowing the ash to be blown by winds and to accumulate into drifts when it was not wet from recent rains.

An excellent exposure of these large-scale cross-beds, probably deposited by wind, occur in the floor of Arroyo Segundo a short distance downstream from the base of Mexicano Falls (Fig. 13). Since the Mitchell Mesa Tuff is not present at this location, it is difficult to determine whether these units are in the uppermost Chisos or lowermost Fresno deposits. McKnight appears to have included them in his lower Fresno when he mapped the area.

FIGURE 13

Cross-bedded sandstone, probably in the Fresno Formation, exposed in Arroyo Segundo downstream from Mexicano Falls. Photo by Dwight Deal

Mud flows, stream-deposited sandstone, and conglomerate are also common within this unit. McKnight (1968:65) comments:

> Most of the fluvial sandstone interbedded with the tuff is only slightly reworked tuff or eolian sandstone. It was perhaps deposited during storms by sheet wash or rill wash off the volcano; rapid deposition of ash probably choked through-flowing streams that might have thoroughly reworked the tuff. Most of the fluvial sandstone contains a greater percentage of accidental fragments; . . . .

The upper part of the Fresno Formation contains abundant conglomerate and sandstone that in some places is interbedded with lava flows. Individual beds range from a few centimeters to six meters thick, and zones composed predominantly of conglomerate and sandstone are up to 4 m thick. A typical such zone exposed in the upper part of Fresno Canyon is described by McKnight (1968:65) as follows:

> It consists mostly of rounded cobbles and pebbles or cherty Cretaceous limestone, but in the upper part of the section it also contains abundant recognizable fragments of Maravillas (Ordovician) black chert; Caballos (Devonian-Mississippian) white, green, and red-brown chert; Tesnus (Carboniferous) red-brown siliceous shale; and "Shutup" (basal Cretaceous) conglomerate.

Trachyandesite Lava Flow (Tfa).—A single distinctive lava flow of mafic trachyandesite is present in the lower part of Fresno Canyon, where it is 35 m (115 ft) thick (see measured section, Appendix 4). Southwest of the Fresno Canyon study area between Arroyo Primero and Rancherias Canyon, the same flow is as much as 100 m (330 ft) thick. This flow pinches out and is discontinuous in the wall of Fresno Canyon about two and one-half km (one and one-half miles) north of the mouth of Arroyo Segundo, but thickens and is present again in the northern part of Fresno Canyon. These outcrops are either part of the same lava flow or are parts of closely associated lava flows that were erupted at approximately the same time as the Bofecillos Vent.

At the base of this flow, a laterally discontinuous 30-cm-thick zone of red-brown and black, flow-banded volcanic glass occurs. This glassy rock was used extensively by local native inhabitants of the area as a lithic resource for the manufacture of stone tools. There are several areas in Arroyo Primero and along Fresno Canyon that were probably old quarry sites. The glassy zone is often beneath debris from the cliffs above, but a little bit of digging through the rubble at the base of the trachyandesite flow usually exposes the glassy zone. This material probably originated as a volcanic ash deposit (tuff) that was melted and fused by the heat of the overriding lava flow. It could also have originated, in total or in part, as the rapidly-chilled base of the flow itself. The fused tuff hypothesis of its origin is the more likely one.

Above the glass is a one-and-one-half-meter zone that grades from highly vesicular (containing many small cavities) near the base to non-vesicular (dense) trachyandesite at the top. Most of the flow is cliff-forming, unaltered, gray, mafic augite trachyandesite. The upper 6 m (20 ft) grades through vesicular trachyandesite to black scoriaceous rubble. The upper meter or so consists of a scoria containing many gravel-sized fragments and a few blocks nearly 30 cm across. This lava flow is exposed in the base of the cliff at Mexicano Falls and along the floor of Chorro Canyon from the Madrid Ranch ruins to Lower Madrid Falls (the "30-foot falls). Lower Madrid Falls is held up by the top of this unit.

Latite Porphyry Lava Flow (Tflp).—Most of the lava flows erupted from the Bofecillos Volcano during Fresno time solidified to form a rock called latite porphyry. The thickest flows are about 65 m (250 ft) thick, but most are less than 30 m (100 ft) thick with an average thickness of 6 to 15 m (20 to 80 ft). They may lie directly on other flows or on thin zones of tuff, sandstone, conglomerate, or volcanic mudflows. McKnight (1968:68) describes them as follows:

> The flows are highly varied: they may erode to steep unscaleable cliffs or relatively gentle vegetated slopes; they may be thoroughly vesicular or scoriaceous or the vesicules may be restricted to thin zones near the top and base; jointing may be columnar, irregular, or follow laminar or swirled flow structure—spacing between joints may be a few inches or several feet; alteration or weathering may be intense or slight and differs with position in the flow; angular or rounded, weathered fragments range in size from gravelly rubble to slump blocks. Texture and composition range widely between flows. Although the average rock is latite, it ranges from trachyte to trachyandesite. Most rock is dark- or light-gray, but much is weathered or altered red-brown from hematite-limonite staining and some is gray-green from interstitial celadonite present either as mottling or distributed through the groundmass. Feldspar phenocrysts are cloudy-white or pink.

One general characteristic of all these volcanic units, particularly the lava flows, is that they can be seen to change thickness quite rapidly as they are traced laterally. The lava flows were erupted onto a topography that had some physical relief and they normally filled valleys that were present at the time of their eruption.

Much of the west wall of Fresno Canyon in the vicinity of the Smith Ranch ruins is dominated by one of these latite porphyry lava flows which forms a very massive cliff. It is extremely well exposed in Arroyo Segundo and is the main cliff-forming unit at Mexicano Falls. The latite porphyry flow is also well exposed in the north wall of Arroyo Primero at the Madrid Ranch ruins but thins rapidly to the south and west and is not present at Madrid Falls in Chorro Canyon.

Sodic Rhyolite Lava Flow (Tfsr).—A lava flow composed of sodic rhyolite up to 3 m (10 ft) thick occurs in the northern part of Fresno Canyon. The outcrops occur on the west side of the canyon, approximately from the mouth of Los Portales Shutup north to the vicinity of Shelter Thrust (near the mouth of the Righthand Shutup). This flow is normally found at or near the base of the Fresno Formation, often resting on top of flaggy Boquillas limestone of Cretaceous age or on massive tuff. The rock is typically a sodic rhyolite containing sparse broken and partially fragmented phenocrysts of quartz, sanidine, and rarely, hornblende. McKnight (1968:71) describes it as follows:

> In some places the rhyolite is brecciated, either by flowage during implacement or by subsequent jointing. The original groundmass texture is everywhere obliterated. The rock is mostly horizontally streaked or layered by undulose discontinuous zones of fibrous chalcedony, and perhaps zeolites in sheaflike colloform bundles; some of the layers are disturbed by stylolites. Interstitial microscopic opaque materials, hydrated iron oxides, and aegirine-augite or riebeckite, color the normally white silica gray to black, red-brown or orange, and gray-green or blue-gray.
>
> The origin is uncertain. The rock is probably not intrusive because it rests on a structurally varied stratigraphic horizon that in some places, particularly in massive tuff, is unsuited for the implacement of a concordant sill. It is probably not a lava flow either, because so silicic a lava would probably be too viscous to spread so thin and extensive a sheet. It is probably pyroclastic; if it were originally a volatile- and alkali-rich vitric tuff, devitrification and extensive alteration could have produced a unit with the observed composition and field relationships. Additional silica and perhaps alkalies were probably added in places by ground water; large bodies of silica mapped about a mile to the north are perhaps completely silicified sodic rhyolite.

Santana Tuff

During the time of Bofecillos volcanic activity, the Santana Tuff was erupted from a vent somewhere to the south of Fresno Canyon, probably in Mexico. It is a welded tuff (ignimbrite) like the Mitchell Mesa Tuff, and, although it covered less area than did the Mitchell Mesa Tuff, the Santana is also highly useful in establishing the relative age of the volcanic units in the region. Like the Mitchell Mesa, the Santana Tuff thins on the flanks of the Solitario indicating that the Solitario was still a positive area at the time of its eruption. The Santana also thins and is absent south of Arroyo Primero on a line between Primero Dome and the Wax Factory Laccolith, indicating these areas were also high. The Santana Tuff is present in the study area only for a short distance on the western side of Fresno Canyon, extending from the vicintiy of Madrid Falls in Chorro Canyon northward as a thin or intermittent unit to the head of Fresno Canyon. It is present at the base of Upper Madrid Falls (the "100-foot falls"), where the thickness of the welded unit is only about 1.2 m (4 ft). It forms a small but distinctively light-colored ledge on the north side of Chorro Canyon and along the west side of Fresno Canyon above the Smith Ranch ruins. Along the south side of Arroyo Segundo, it is separated from the underlying massive cliff of latite porphyry in the Fresno Formation by a thin layer of Fresno Tuff, but at Mexicano Falls and on the north side of Arroyo Segundo it rests directly on the latite porphyry.

One of the few minor errors located during the field-checking of McKnight's map (1970) occurs just upstream from the top of Mexicano Falls. This is a remote and difficult place to visit, and I assume that McKnight mapped this particular area from aerial photographs. The Santana Tuff extends upstream from the junction of Arroyo Segundo and the drainage that comes south from Chilicote Springs (marked, probably erroneously, on the U.S.G.S. Sauceda quadrangle map as the "Smith House Spring"). The Santana does extend several hundred meters farther north than indicated on McKnight's map and is in fault contact with the overlying Rawls Formation to the west.

Rawls Formation

About the time the Santana Tuff was spread over the area, the eruptions from the Bofecillos Volcano became more complex. More and more lava flows were erupted, not only from the central vent area but from fissures in and around the eruptive center. Ash-fall and ash-flow tuff layers were spread over the Fresno Canyon area, probably both from the Bofecillos vents and from over vents in the surrounding area. Later flows from the Bofecillos Vent were predominantly basaltic. Block faulting began before extrusion of the uppermost basalt flows, causing them to be interbedded with sedimentary rock in the downdropped fault blocks. McKnight mapped the Rawls Formation in considerable detail, mapping 24 stratigraphic units (McKnight 1968; Deal 1976b). Only 10 are present in the Fresno Canyon study area, and by far the most important unit is the series of basalt porphyry flows (McKnight's $Tr4_{bp}$). These units are described in more detail in the companion volume on the Bofecillos Mountains (Deal 1976: Appendix 1).

In the central part of the study area between Madrid Falls in Chorro Canyon and Mexicano Falls in Arroyo Segundo, four Rawls units are present. They are, in ascending order from oldest to youngest, Member 4 trachybasalt porphyry lava flows ($Tr4_{bp}$) and trachyandesite lava flows ($Tr4_a$), younger Member 8 trachyandesite lava flows ($Tr8_a$), and Member 9 basalt flows ($Tr9_b$).

South of Arroyo Primero, two older units are present between the top of the Fresno Formation and the basalt porphyry flows; these include a basal Member 1 unit consisting of basalt lava flows and interbedded sedimentary rock ($Tr1_b$) and a Member 3 latite porphyry lava flow and interbedded sedimentary rock ($Tr3_{1p}$). Also in this area, mappable thicknesses of Member 9 sedimentary conglomerates and sandstones (bolson fill, $Tr9_f$) occur beneath the base of the uppermost basalt lava flows ($Tr9_b$).

In the northern part of the study area at the head of Fresno Canyon, more basal Member 1 basalt ($Tr1_b$) trachybasalt lava flows and sedimentary rock occur along with some Member 2 tuffs ($Tr2_t$) and sedimentary rocks below the Member 4 trachybasalt porphyry lava flows ($Tr4_{bp}$). In addition some Member 7 units occur, including a latite porphyry lava flow ($Tr7_{1p}$) and a partially welded ash-flow tuff ($Tr7_{at}$).

The four major units that occur in the Fresno Canyon area (Member 4bp, 5a, 8a, and 9b) are described below. Additional descriptions of these and the other Rawls units are given by McKnight (1968) and included in Appendix 1 of the companion volume on the Bofecillos Mountains (Deal 1976b).

Member 4, Trachybasalt Porphyry Lava Flows (Tr4bp).—This unit contains a sequence of trachybasalt lava flows, the most characteritic ones consisting of a distinctive trachybasalt porphyry that contains large tabular crystals of plagioclase feldspar (these inclusions are called phenocrysts) in a dark, fine-grained basaltic matrix. As much as 40% of the rock may be made up of the large plagioclase crystals which are up to 6 cm in length. Even the longest crystals may only be a few millimeters thick, however. The feldspar phenocrysts weather white to gray, and on weather surfaces are very conspicuous against the red-brown, gray or black background of the groundmass. In many places numerous red-brown smaller grains of iddingsite give the groundmass a sparsely speckled appearance.

The trachybasalt porphyry lava flows range from a few meters to about 15 m (50 ft) in thickness. The bottom of the lava flows commonly consist of a non-resistant and crumbly basal flow breccia, a few centimeters to a meter or more thick and containing pebble- to boulder-sized scoriaceous blocks of altered trachybasalt porphyry. These zones are often quite porous even though the fractures and cavities are partially to totally filled with calcite, chalcedony, and celadonite. The middle part of each flow is the most resistant to erosion, commonly standing as steep but rounded and generally scaleable cliffs, but has sufficient porosity and fracturing so that it is weathered throughout, making it difficult to obtain fresh had specimens of this material (McKnight 1968:92). The top of the trachybasalt porphyry lava flows is quite porous (highly scoriaceous) and weathers red-brown. The uppermost meter or so is a clinker-like rubble of boulder- to sand-sized fragments that commonly grades into the basal flow breccia of the next higher flow.

These porous zones are extremely important to the hydrology of the area, as they form the main groundwater aquifer in the region. Almost all of the bedrock springs that feed Arroyo Segundó, Chorro Canyon, and Arroyo Primero issue from this unit. The entire box canyon above the top of Madrid Falls is within this unit, and the springs there as well as the springs in Arroyo Segundo above Mexicano Falls (Ojo Mexicano, the springs around Segundo Dome, and the spring area around Chilicote Springs) issue from it. Several of the lower flows in this unit form the resistant lip of Upper Madrid Falls.

Most of the trachybasalt porphyry flows probably did not erupt from the main Bofecillos vent area, but from the vents on the north flank of the volcano in what is now the Lava (Leva, Laeva; pronounced locally "lay-va") Canyon area. Dietrich (1965: geologic map and 127-128) mapped thick dikes of trachybasalt porphyry and noted that the thickest section of the trachybasalt porphyry flows occurred in that area. McKnight (1968:92-93) noted that some thin dikes and small intrusions of the same material, probably the source of some of the flows, also occur in the central Bofecillos Mountains.

Member 5, Trachyandesite Lava Flow (Tr5a).—Rawls Member 5 is characterized by an extrusion of trachyandesite lava that began before the eruption of the commonly underlying trachybasalt porphyry lavas, characteristic of Member 4, ceased (McKnight 1968:95). The resulting interlaying and interfingering of the two rock types make the contact between the two members more or less arbitrary. McKnight placed the contact beneath the lowest trachyandesite flow that he could laterally trace to some location where he was sure that the section consisted dominantly of trachyandesite.

The trachyandesite of Member 5 spread as flows a few meters to about 15 m thick. The basal flow breccia is generally less than 30 cm thick, and above this the rock is brown- to olive-green-weathering, nonvesicular, gray trachyandesite commonly mottled with yellow-brown to gray-green celandonite or zeolites. The flow tops may be festooned with pressure ridges several feet apart. This rock has essentially the same mineral composition as the trachyandesite (Tfa) of the Fresno Formation.

Although a narrow band of this unit is exposed immediately north of Madrid Falls, the flow does not extend south of Chorro Canyon. It occurs above the basalt porphyry escarpment between Chorro Canyon and Arroyo Segundo but is absent on the north side of Arroyo Segundo. It occurs again in some outcrops in the northern part of the Fresno Canyon area.

Member 8 Lava Flows (Tr8a and Tr 8bp).—Most of the plateaus above and west of Fresno Canyon are capped by lava flows that belong to Member 8. Between Arroyo Primero and Arroyo Segundo they consist only of the upper part of Member 8, a series of trachyandesite lava flows (Tr8a). These are very similar to the trachyandesite flows of Member 5 described above and are difficult to tell apart when the intervening units are not present. North of Arroyo Segundo the intervening rocks are present and cap most of the higher mesas. Some exposures of Member 7 ash-flow tuff occur immediately on top of the Member 5 trachyandesite flows, and they in turn are overlain by a fairly thick sequence of the lowermost part of Member 8: trachybasalt porphyry lava flows (Tr8bp). Individual flows in this unit are generally less than 15 m thick, have a gray, rather than black, groundmass, and weather pale gray rather than red-brown.

Member 9, Basalt Flows (Tr9b).—In contrast to the earlier flows in the Rawls Formation, many of the basaltic flows of Member 9 were extruded after appreciable block faulting. As a consequence Member 9 flows are interbedded with the thick sequence of graben-filling sedimentary rock. Several kilometers west of Chorro Canyon in the headwaters of Arroyo Primero (northeast of Panther Dome), Member 9 is more than 90 m (300 ft) thick and is composed mostly of sedimentary conglomerate. The basalt flows of Member 9 cap mesas in the southwestern part of the Fresno Canyon study mesa, from Rincon Mountain southwestward across the headwaters of Chorro Canyon to the headwaters of Arroyo Primero. Individual basalt flows are generally less than 15 m (50 ft) thick. McKnight (1970) shows several small patches of Member 9 basalts on the eastern side of Fresno Canyon northeast of the mouth of Arroyo Segundo between Fresno Creek and the base of the steeply-dipping beds that surround the Boquillas Formation and tuffs of the Chisos Formation. If McKnight is correct and these are the same rocks that cap Rincon Mountain, considerable topographic relief existed in the Fresno Canyon area prior to the eruption of Member 9 basalts. One outcrop in the canyon floor is about one and one-half km (less than a mile) northeast of the 305 m (1000 ft) below the summit of Rincon Mountain.

Tertiary Intrusive Rocks

Dikes and sills are abundant in and around the Bofecillos Vents to the west but are not common in the Fresno Canyon area. Those that do occur are relatively small and would not be mappable at the scale used by McKnight in his study of the area.

The most important types of intrusions in the Fresno Canyon area are the laccoliths that have been implaced into the flaggy limestones of the Boquillas

Formation. Laccoliths are intrusions that have an upside-down, saucer-like shape with a generally horizontal base and a domed top. Several intrusions of this type occur in the Contrabando Lowland south and east of most of the study area. Probably the largest of these is the Wax Factory Laccolith, well exposed above Fresno Creek just to the west of the Fresno and Whitroy mines. The road to Fresno Canyon from the south enters the bed of Fresno Creek at this point. The Wax Factory Laccolith has been described in detail by Lonsdale (1940) and is as much as 46 m (150 ft) thick and at least 3.2 km (2 miles) across. It is composed of the rock type called syenodiorite and is characterized in hand specimen as a medium- to fine-grained rock that is black to gray where fresh, commonly altered to an olive-green or white.

A number of similar clustered laccoliths and sills occur both east and southwest of the Wax Factory Laccolith. Additional similar intrusions probably exist at depth because the intrusions commonly dome overlying strata and a number of domes occur that have not yet been eroded enough to expose their cores. McKnight (1968:105) also reports that holes drilled in Contrabando Dome in search of mercury deposits penetrated several layers of igneous rock similar to that in the intrusions exposed on the surface. He describes the outcrops as follows:

> The exposed bodies are in all stages of dissection, and arroyos incised through the intrusions provide excellent cross-sections exhibiting a diversity of forms and contact effects. Bases are generally not faulted, but they may arch or sag; tops may be symmetrical or asymmetrical and the arching may be uniform or the sides steep and the crown relatively flat. The roof is commonly faulted and dikes or intrusive wedges commonly extend upward into the overlying limestone; at least one body is a trapped door laccolith. Limestone is baked gray, recrystallized, and partially silicified a few feet to several tens of feet from the contact.

Similar intrusive bodies are probably the cause of the domal uplifts that occur to the west of Fresno Canyon (Primero Dome in the head of Arroyo Primero and Segundo Dome and Little Dome at the head of Arroyo Segundo). Bogles Domes at the head of Fresno Canyon are more complex features and are described in more detail by McKnight (1968:107) and Deal (1976b) in a companion report on the Bofecillos Mountains.

TERTIARY AND QUATERNARY FAULTING

There are two types of faulting which occured in the Fresno Canyon area during late Tertiary and Quaternary time: near-vertical faults with vertical displacements (normal faults) and thrust faults interpreted as having resulted from the sliding of large slump blocks.

Vertical Faults

A number of vertical to near-vertical normal faults with displacements of as much as 600 m (2000 ft) occur around the flanks of the Bofecillos Volcano to the west and southwest of the study area. These major faults follow regional trends and were probably active during the period of Tertiary volcanism. Such faulting may have been the cause of some of the relief in the vicinity of Rincon Mountain that developed prior to the eruption of the Member 9 basalts of the Rawls Formation (see earlier discussion of Rawls Member 9).

Continued displacements along these faults has occurred since the cessation of volcanic activity, probably continuing well into the Quaternary. Activity along the vertical faults was associated with the development of the horst-and-graben topography along the Rio Grande valley, described in more detail by McKnight (1968:121-126) and in the companion volume on Colorado Canyon (Deal 1976b). Vertical faults are not too obvious in the Fresno Canyon area. One major northwest-southeast trending series of faults cut the walls of Arroyo Primero just south of the Madrid Ranch ruins. Normal fault displacements are more obvious southwest of this location outside of the Fresno Canyon study area.

One small normal fault is very clearly exposed in the floor of the northern part of Fresno Canyon, just south of the Shelter Thrust. This normal fault trends east northeast to west southwest across Fresno Canyon and passes just north of the mouth of the Righthand Shutup. The Boquillas Limestone is upthrown on the northwest side of this fault and the fault trace is marked by a prominent pouroff over the Boquillas Limestone in the bed of Fresno Creek.

Several other vertical faults occur in the northern Fresno Canyon area and appear to be aligned more or less radially away from the Solitario Uplift (Corry 1972: geologic map; a modified version of which is included in Deal 1976b). A major vertical fault is shown on Corry's map following the curving western edge of the Santa Elena Limestone outcrop along the outside of the Solitario rim escarpment. This fault extends along the entire eastern side of upper Fresno Canyon and appears to be a detachment fault entirely associated with the gravity sliding discussed below.

Gravity-Slide Thrust Faults

Numerous faults in the Fresno Canyon study area are obviously the result of large blocks sliding, under the influence of gravity, down into Fresno Canyon.

FIGURE 14

The shelter at Shelter Thrust in Fresno Canyon. A landslide block of Buda Limestone has moved toward the camera, overriding beds of the younger Boquillas Formation. The softer Boquillas beds have eroded from beneath the Buda to form the shelter (see also Figs. 15 and 16). Photo by Dwight Deal.

FIGURE 15

The nose of the Shelter Thrust gravity-slide block. Buda Limestone, sliding into Fresno Canyon from the flank of the Solitario Uplift has bulldozed beds of the Boquillas Formation. See also Figure 16. Photo by Dwight Deal

One group of these is associated with the doming of the Solitario Uplift and involved blocks of Buda Limestone and some Del Rio Clay sliding radially outward from the uplift. Sliding took place on planes of weakness that developed in both the Del Rio Clay and in the Boquillas Formation (McKnight 1968:117-120; Corry 1972:76-77). A beautifully exposed example of this type of gravity-slide thrusting occurs just north of the mouth of the Right-hand Shutup on the eastern side of Fresno Creek at the location known as the "Shelter Thrust" (Fig. 14). The base of the thrust plane is exposed in the roof of a shelter a few meters east of the roadbed of the old Marfa-Lajitas highway through Fresno Canyon. The shelter was extensively used by Indians and has a smoked roof showing both positive and negative painted handprints. The archaeology of this shelter is described in the accompanying archaeological section. The thrust plane is nearly horizontal at the shelter and the grooving on the side of the thrust is well exposed in the shelter ceiling. A few meters south of the shelter the leading edge of the sliding block of Buda Limestone is dramatically exposed where it pushed into the flaggy Boquillas Formation (Fig. 15). Erosional remnants of slide blocks like this are called "klippe." McKnight (1968:118) describes the Shelter Thrust as follows:

> The Shelter Thrust is a nearly horizontal fault named by Dietrich and Maxwell beneath a klippe in the central part of Fresno Canyon; an overhang on the west side of the klippe has a smoky roof and hand prints typical of

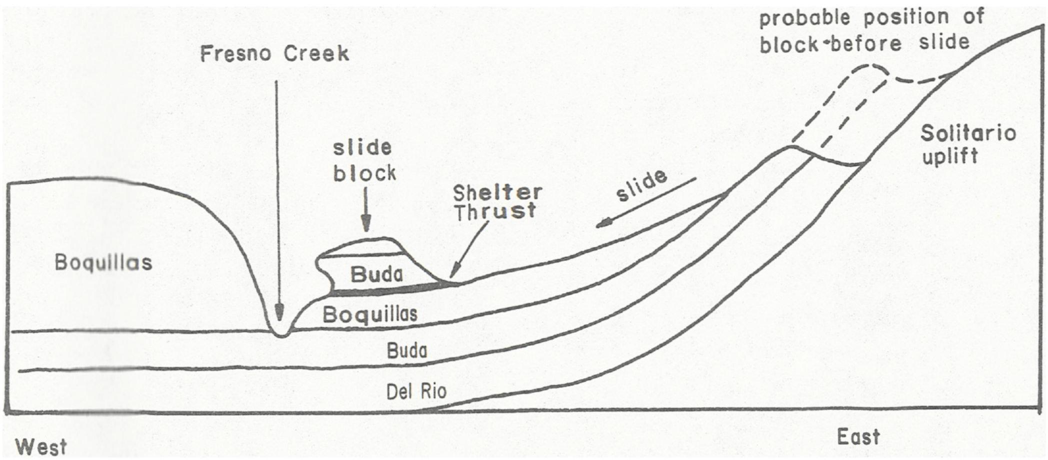

FIGURE 16

Diagrammatic cross section showing interpreted gravity-slide origin of Shelter Thrust. Redrawn from McKnight 1968: Fig. 14.

ancient Indian shelters in the Big Bend region. The klippe is about 200 feet across; it rests on the lower part of the Boquillas Formation about 30 feet above the base and consists of about 20 feet of Buda Limestone overlain by five feet or less of Boquillas Formation. The klippe probably slid to its present position from a hogback of Buda Limestone about 2,000 feet to the east and several 100 feet higher, over clay-rich colluvium from the Del Rio and Boquillas Formations (Fig. 16); it is not a remnant of a west-dipping tectonic thrust because the fault is not present in a cliff a few 100 feet to the west.

The detachment plane of a series of similar slide blocks extends entirely along the western margin of the Solitario Uplift (Corry 1972:76-77 and geologic map; a modified version of that map is included in Deal 1976a). Corry shows the detachment plane as a vertical fault along the contact between the Santa Elena Limestone and Del Rio Clay, extending in an arc from the northern part of Fresno Canyon southeastward to the Lower Shutup.

Both east and west of the Smith Ranch ruins are a number of rotational-slump blocks in which fairly large masses of the latite porphyry lava flow (Tflp) and underlying units of the Fresno Formation have slid downhill toward Fresno Creek and its tributaries. The most obvious of these blocks is immediately northwest of the Smith Ranch ruins on the north side of the gully leading up to the Smith House Springs. Two kilometers east of the Smith Ranch ruins is a series of a dozen or so similar slump blocks that are very obvious on aerial photographs. All of these are shown on McKnight's (1970) geologic map (also *in* Corry 1972 and Deal 1976a).

A low-angle thrust fault exposed on the east side of Fresno Canyon approximately 100 meters south of its junction with Arroyo Primero was named the Benchmark Thrust by McKnight (1968:120-121). He describes it as follows:

> A low-angle thrust is strikingly exposed in Fresno Canyon, about a 100 yards south of its junction with Primero Creek near bench mark R749 (elev. 3,013); it is covered to the west by younger strata and it dies out to the east along the crest of a chevron fold. The thrust occurred during the deposition of the lower part of the Chisos Formation because the Jeff Conglomerate is faulted and the fault is overlain unconformably by the Mule Ear Spring Tuff. It is probably not a regional Laramide structure because such thrusting is atypical of Laramide deformation in the block between the Coahuila and Diablo Platforms, and because it occurred after the Jeff was deposited–a conglomerate interpreted as following most of the Laramide acitivity. For these reasons, and because this mechanism is consistent with the interpreted mode of formation of other thrusts in the area the structure is probably a gravity slide. There is no indication–doming, complex normal faulting or hydrothermal alteration–of an intrusion at depth that might have caused the thrust.

A complex of imbricate thrust faults involving at least 15 repetitions of the Mule Ear Spring Tuff Member of the Chisos Formation is dramatically exposed in the southern part of the study area on the east side of Fresno Creek about four kilometers airline distance southeast of the Smith Ranch ruins. This location is approximately 300 m upstream from McKnight's (1968) measured section number four (see Appendix 4). He refers to these as the Fresno Canyon imbricate thrusts and describes them as follows:

> In this area, the Mule Ear Spring Tuff rests on tuff a few feet above clay in the upper part of the Boquillas Formation; above the Mule Ear Spring is about 20 feet of tuff overlain by 100 feet of Tule Mountain Trachyandesite Porphyry. The thrusting probably occurred when a block of Tule several 100 feet long broke loose from the rest of the unit and slid downslope over the Boquillas clay; Mule Ear Spring, dragged under the block, broke into imbricate slabs along the slide plane. The unstable slope that caused the sliding may have been created by intrusive uplift of the Solitario or Terlingua Monocline, or it may have been formed at a later time when Fresno Creek or its ancestral equivalent eroded away the toe of the slope.

TERTIARY AND QUATERNARY SEDIMENTARY DEPOSITS AND EROSIONAL HISTORY

Sedimentary fill in the basins along the Rio Grande accumulated during late Tertiary and Quaternary time. After an initial period of basin filling, the bolsons were breached and a through-flowing Rio Grande or Rio Conchos established its course across a series of previously isolated desert basins that did not have external drainage. Later deposits in the basins are intimately associated with the development of the Rio Grande and Rio Conchos drainages through the Big Bend area and are discussed in more detail in the companion volume on Colorado Canyon of the Rio Grande (Deal 1976c). The Rio Grande experienced alternate times of rapid downcutting and relative stability, and the tributaries of the Rio Grande in the study area reflect those alternations. The alternations are caused by an interplay between two sets of processes: slope processes (all those processes that carry material downslope and provide sediments to the main streams) and the stream processes (those processes that determine the ability of the main streams to transport material toward the ocean and cut their channels).

When the stream processes can carry away all the material that is supplied from the neighboring hill-sides by slope processes, the main streams excavate their channels, downcutting and lowering the floor of the main drainages. When slope processes dominate and provide more material than the stream processes can transport, the main drainages are filled with sedimentary material and valley filling occurs. When slope processes and main stream processes are in balance, conditions traditionally referred to as "stability" occur and, in arid and semi-arid regions, sloping surfaces of lateral planation (pediment surfaces) are developed on each side of the main stream. During times of more rapid downcutting the streams incise the previously formed planation surfaces. The resultant stair-step-like sequence of gravel-mantled pediments and terraces is strikingly exhibited along the lower portions of Fresno Creek where McKnight 1968:111-115, 127; 1970: geologic map) maps four pediment and terrace gravel deposits in addition to the modern stream sediment.

The deposits in the Fresno Canyon area reflect a sequence of events occurring along the Rio Grande and defined in the Redford Bolson west of the study area. McKnight correlated the deposits in the Redford Bolson with those along the Rio Grande in the Santana Bolson (west of the junction with Fresno Creek), and then with the gravels in the Contrabando Lowland, Fresno Canyon and other side streams to the Rio Grande. He describes his correlation of them as follows:

> The most extensive pediment and terrace deposits are in the Redford Bolson where four gravel sheets are numbered in order, in accordance with the system started by Amsbury (1959) and modified by Dietrich (1965:168); the highest (oldest) is Qgl and the lowest Qg4. Only a few remnants are preserved of the pediment gravel Qg1; mostly they are close to and sloping steeply from the high-standing parts of the Bofecillos Mountains. The gravel projects everywhere to about the same height above the Rio Grande, but the remnants are so widely separated and far-removed from the river that the correlation expressed by the symbol Qg1 is very loose and does not imply a single period of base level stability. Gravels Qg2 and Qg3 are remnants of extensive sheets mapped by Dietrich (1965) in the Presidio Bolson and in the northwest part of the Redford Bolson. Gravel Qg4 includes all pediment and terrace deposits between gravel Qg3 and flood plain alluvium of the Rio Grande and its tributaries.
>
> Two extensive gravel sheets in the Santana Bolson are tentatively correlated with Qq1 and Qq2 of the Redford Bolson, which they resemble in projected height above the Rio Grande, degree of cementation and dissection, and tone on aerial photographs. On the same basis, three gravel sheets that extend across Contrabando Lowland and into Fresno Canyon are tentatively correlated with Qg2, Qg3, and Qg4 of the Redford Bolson. Elsewhere in the map area, pediment and terrace gravels are undifferentiated Qg.

Pediment and terrace gravels along Fresno Creek range from a meter or so to almost 10 m thick. Most are poorly sorted and contain angular to subrounded cobbles to boulders of volcanic and sedimentary rocks in a sandstone matrix. Boulders can be more than a meter in diameter. The volcanic rock types are like those in Rawls and Fresno flows in the adjacent western hills and are generally dark colored. Most of the sedimentary fragments are of light-colored limestone eroded from the rim escarpment of the Solitario on the east, but some are white, green, and black chert and other rock types from the Paleozoic section exposed within the Solitario. Gravels on the west side of the canyon tend to contain mostly dark-colored volcanic fragments while those on the east contain mostly light-colored sedimentary rocks. McKnight continues:

> The matrix is coarse- to fine-grained volcanic sand, locally cemented by caliche. Cementation is greatest in the Qg2 and Qg3 gravels; it is not yet well developed in the Qg4 gravel, and in the Qgl gravels the cement has been partly removed by leaching.
>
> In and adjacent to the Rio Grande valley, alluvium deposited by the river is designated Qalr and that deposited by side stream Qals; elsewhere it is mapped as undifferentiated Qal.
>
> Rio Grande alluvium is of two types. Channel gravel is made up of rounded pebbles, cobbles, and boulders, mostly volcanic, as much as three feet in diameter, with interstitial sand and silt; it resembles the Rio Grande terrace gravel included in Qg2 and Qg3. Flood plain deposits are markedly different, consisting of medium- to fine-grained, well bedded, buff, clay-rich silty sand with sparse large boulders that were probably floated to their present position while entangled in tree roots. Except in the present channel, the coarse gravels are covered almost everywhere by the flood plain deposits; buried channels are marked by lines of cottonwood trees and salt cedar, both of which flourish over these aquifers.
>
> Most side-stream channels are dry except during storms when flash flooding is common. The alluvium is sandy gravel and gravelly sand resembling that preserved on the pediments. In the mountains, slump or landslide blocks may clog the channel, moving downstream only during flash floods; in the bolson, however, the larger boulders are four feet or less in diameter. Composition of the gravel reflects the geology of the drainage basin.

Slope deposits (colluvium) are the most common unconsolidated sedimentary material in most of the Fresno Canyon study area. It ranges from a thin veneer of soil to large piles of bare talus. McKnight (1970) was interested in the bedrock stratigraphy and mapped slope deposits only where the talus cover was "so thick that an attempt to infer the underlying geology is not warranted."

MINERAL RESOURCES

Mercury

The Terlingua quicksilver district adjoins the southeastern part of the study area and extends eastward for about 35 km. A good history of the development of the Terlingua mercury district was prepared by Daugherty (1972) and is reproduced as Appendix 3 to this report.

According to Chester (1965) the Fresno Mine and the low-grade mineralization on the Contrabando Dome on the east side of Fresno Creek were discovered in 1935. This extended the known belt of mineralization about 10 km to the west. Most of the development in the Terlingua District is along a marked east-west trend. This also parallels the axis of the Terlingua Monocline. Metallization of the Terlingua District may extend along established trends in either of two directions from the Fresno Mine: 1) westward, along the same trend as to the east or 2) northward, paralleling the trend of the Terlingua Monocline toward the Solitario Uplift. North of the vicinity of the Fresno Mine, volcanic strata are mostly stripped from the beds known to be the most favorable host rocks in the Terlingua District (McKnight,1968:137). McKnight describes the potential for mercury prospects in the Fresno Canyon area as follows:

> Westward, a 1,000-foot thick section of Tertiary volcanic strata blankets the zones which are mineralized in Cretaceous rocks in the District proper and economic exploitation at these depths seems unlikely in the near future. Prospecting to the west should examine the possibilities of finding mercury deposits in northeast-trending fractures in the volcanic and intrusive rock; such occurrences of mineralization would have relatively little chance of being mineable ore bodies. Attention might better be focused on intrusive domes where Cretaceous strata are nearer the surface. Rancherias Dome is probably the most favorable of the known domes because there are Cretaceous strata at the surface, numerous siliceous fissure veins, and abundant iron oxide stains.
>
> North of the Terlingua District, volcanic strata are mostly stripped off the strata known to be favorable host rocks (Fig. 7) in the Terlingua District. The area of interest extends from the Fresno Mine north to where the monocline abuts against the Solitario and perhaps along the west–and even east–side of the Solitario. Siliceous fissure veins and replacement mantos are common in parts of Fresno Canyon along this general trend. Furthermore, calcite veins are common in Cretaceous strata; although many were probably deposited by ground water, hematite staining in some suggests hydrothermal activity. A prospect along this trend is a dome about three miles northwest of the Fresno Mine and a mile southwest of the abandoned Smith Ranch in Fresno Canyon (Fig. 7). At this place numerous faults cut three southeast-trending anticlines that expose the lower part of the Boquillas Formation. A few of the faults are hematite stained; the faults trend southeast to east but bear approximately the same angular relationship to the monocline—here trending north to northwest—as do the mineralized fractures in the quicksilver district. The basal flow breccia of the lowest lava flow (Tf-lp) contains abundant chalcedonic silica of probable hydrothermal origin, and such silica also abounds in the float. After carefully mapping the area—about three-fourth mile across—one might be able to determine the depth of the Del Rio-Santa Elena contact and define targets by projecting mineralized faults to this surface. A mercury vapor detection apparatus might be useful in locating more subtle targets in this area.

Bentonitic Clay

Some of the volcanic ash interbedded between the lava flows that issued from the Bofecillos Volcano and now exposed along the western edge of Fresno Canyon contains bentonitic clay. I do not know if these deposits meet industry's specifications and are present in sufficient volume to be of economic value. McKnight (1968:139) discussed the prospects for bentonitic clay in the general Bofecillos Mountains area as follows:

> Some of the tuff in the area, particularly that in the lower parts of ash flows, contains bentonitic clay that might be of economic value if it meets industry specifications and is present in sufficient volume. Dietrich (1965) reported prospect pits in the Fresno Formation at the west end of the map area northwest of Carrasco Dome, but they were of little economic interest. At the south end of Tapado Dome, a three- to six-foot bentonitic zone of unknown lateral extent at the base of the Mule Ear Spring Tuff is remote from good roads and has a thick overburden laced with lava flows. It would not be amenable to stripping without drilling and blasting. Bentonitic clay probably exists partly or totally covered elsewhere in the map area. The base of the Santana Tuff is probably the most likely stratigraphic interval for an economic deposit because it is part of a thick unit and therefore has at least the potential of containing a thick deposit; furthermore this part of the Santana is mostly covered by talus from the steep slopes above—possible deposits near the base are therefore covered.

Flourspar

Flourspar is a basic raw material in the chemical, metallurgical, and ceramic industries. The numerous deposits of flourspar that exist in Trans-Pecos Texas have been described by McAnulty (1974). Several

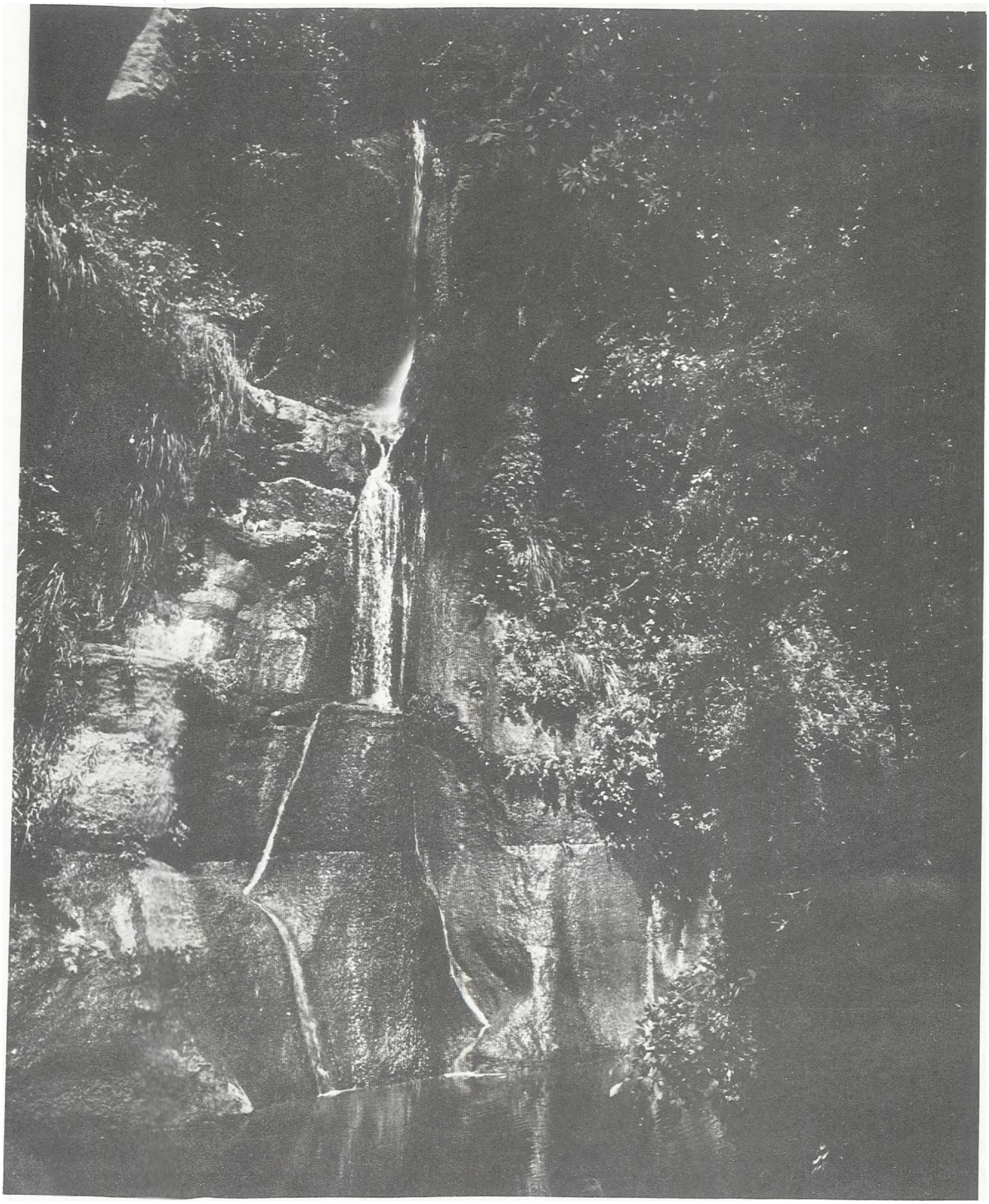

FIGURE 17

Photo by Reagan Bradshaw

Madrid Falls in Chorro Canyon, a tributary of Arroyo Primero.
This photograph of the splash pool at the base of the upper falls was taken during low flow (probably minimum flow) conditions in early August, 1975.
Springs also feed this pool—more water flows out than falls in from above.

occurrences are known south and east of Fresno Creek (McAnulty 1974:12, Fig. 5).

Flourine is a characteristic constituent of some alkaline magmas, and almost all commercial deposits appear to have formed directly or indirectly from fluids of magmatic origin. Commercial deposits are known in all types of host rocks as void fillings; as replacement veins along faults, fractures, shear zones, breccia pipes, and other brecciated areas; as irregular-shaped replacement bodies in contact zones, and as extensive concordant replacement deposits (mantos) in limestones and calcareous shales. Weathering of primary deposits sometimes results in residual deposits of gravel spar (McAnulty 1974:2-3).

Since most of the commercial deposits of flourite in the Big Bend occur in limestones, the most favorable areas to prospect would be in the limestone outcrops in the immediate vicinity of igneous intrusions in the Solitario and Contrabando Lowland along Fresno Creek. Ore bodies may also exist in the limestones beneath the volcanic rocks of the Bofecillos Mountains.

Water Resources

The most important mineral resource in the Fresno Canyon area is probably water. The presence of perennial flowing water, numerous springs and seeps, and several waterfalls in an otherwise typically arid Chihuahuan Desert landscape, make this area one of unusual aesthetic and scientific interest. Fresno Canyon and its tributaries to the west that head in the Bofecillos Mountains tap part of the hydrologic system that underlies the volcanic field. The hydrology and groundwater situation there is described in much more detail in the companion volume on the Bofecillos Mountains (Deal 1976b). The water resource section of that report should be consulted when developing any new water management plan for the Fresno Canyon area.

Two basically different types of springs and seeps occur: 1) those that result from groundwater discharging from bedrock aquifers in the underlying volcanic and sedimentary rocks ("primary springs)) (Fig. 2) and 2) those that occur in the bottom of arroyos where resistant and impermeable strata force the water that is moving through the unconsolidated sand and gravel to the surface (Figs. 8 and 12).

Almost all the springs and seeps that occur in the study area are found either in Fresno Creek or in western tributaries. The eastern side of Fresno Canyon, with drainages heading in Cretaceous carbonate strata and the Solitario, is much more arid. Standing water can occasionally be found in tinajas (water-filled bedrock depressions) in the shutups that drain the Solitario (see companion volume on the Solitario, Deal 1976a). A major tinaja in the Lower Shutup is a fairly dependable source of water.

Chorro Canyon, Arroyo Primero, and Madrid Falls

Madrid Falls in Chorro Canyon is a true gem of the Chihuahuan Desert (Figs. 17, 18, and 19). The area has been described in some detail in other parts of this report and by McKann (1975) whose thesis work was an outgrowth of an earlier file report by the Texas General Land Office (McKann and others

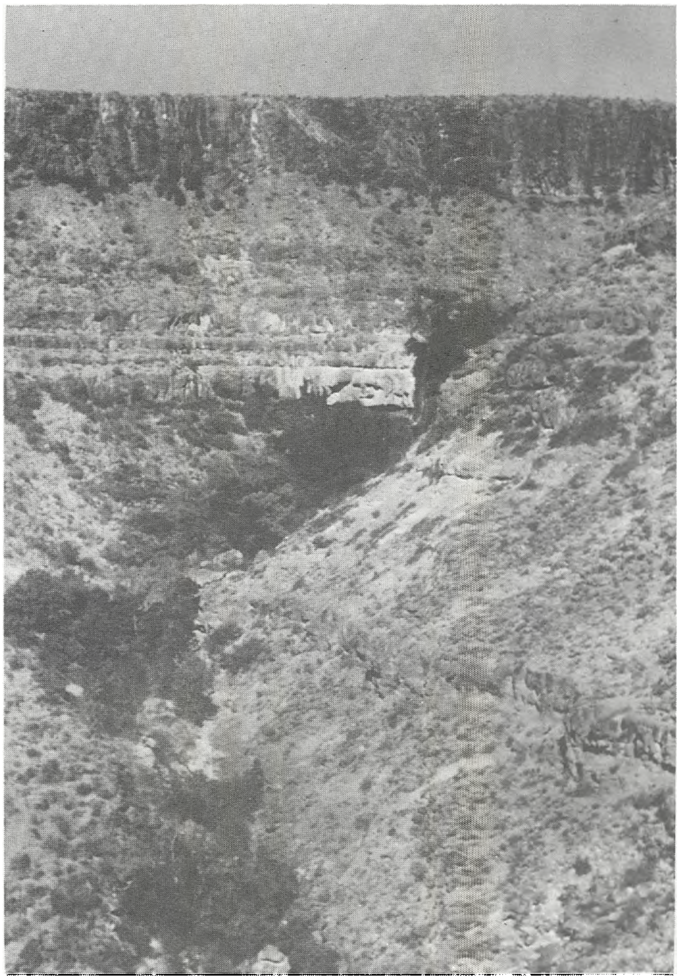

FIGURE 18

Dense vegetation hides Madrid Falls. Lower Madrid Falls flow over the mafic trachyandesite lava that forms the lower cliff on the right side of the canyon. A basalt porphyry cliff holds up the higher Upper Madrid Falls. A very thin bed of Santanna Tuff forms a ledge just below the basalt porphyry cliff (see also Fig. 20). The lip of Upper Madrid Falls (see also Fig. 19) is hidden behind the highest patch of dense vegetation visible, which is at the downstream end of the extremely moist habitat occurring in the 1 km-long box canyon above the falls.

Photo by Dwight Deal

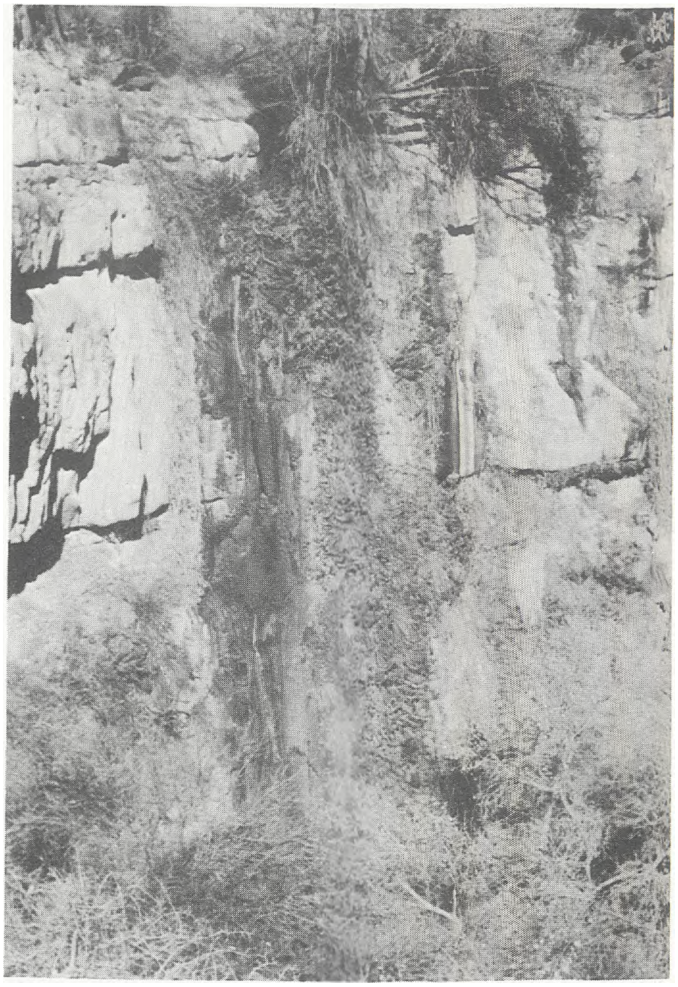

FIGURE 19

The lip of Upper Madrid Falls in January, 1972. Low flow (probably minimum flow) conditions. The falls are almost completely hidden by lush vegetation in other seasons.
Photo by Dwight Deal

1973). Figure 20 is a longitudinal geologic profile of Chorro Canyon and lower Arroyo Primero from that report.

The perennial flow over Madrid Falls is fed by a series of springs that occur in the approximately one-kilometer-long box canyon immediately above the upper falls. The springs are fed by water moving through porous zones at the top and bottom of individual basalt porphyry lava flows in McKnight's $Tr4_{bp}$ member of the Rawls Formation, the base of the Rawls Formation in Chorro Canyon. Additional springs supplying water from the bedrock apparently occur at the base of the upper Madrid Falls (the "100-foot falls"). This is indicated by the fact that more water flows out of the splash pool at the base of the falls than enters from above, and because the water in the splash pool is noticeably cooler than the surface water which comes over the upper falls. Lower Madrid Falls (the "30-foot falls") are held up by a mafic trachyandesite lava flow in the upper part of the Fresno Formation. Surface water normally flows about one km down Chorro Canyon below Lower Madrid Falls, almost to the junction with Arroyo Primero. Numerous springs occur along the length of Arroyo Primero, but most of these are located where resistant beds force the groundwater that is flowing in the unconsolidated stream sediments to the surface.

Arroyo Segundo and Mexicano Falls

Most of the water flowing over Mexicano Falls (Figs. 21, 22, and 23) in Arroyo Segundo is initially discharged from bedrock springs several kilometers upstream from the falls. The most distant are Ojo

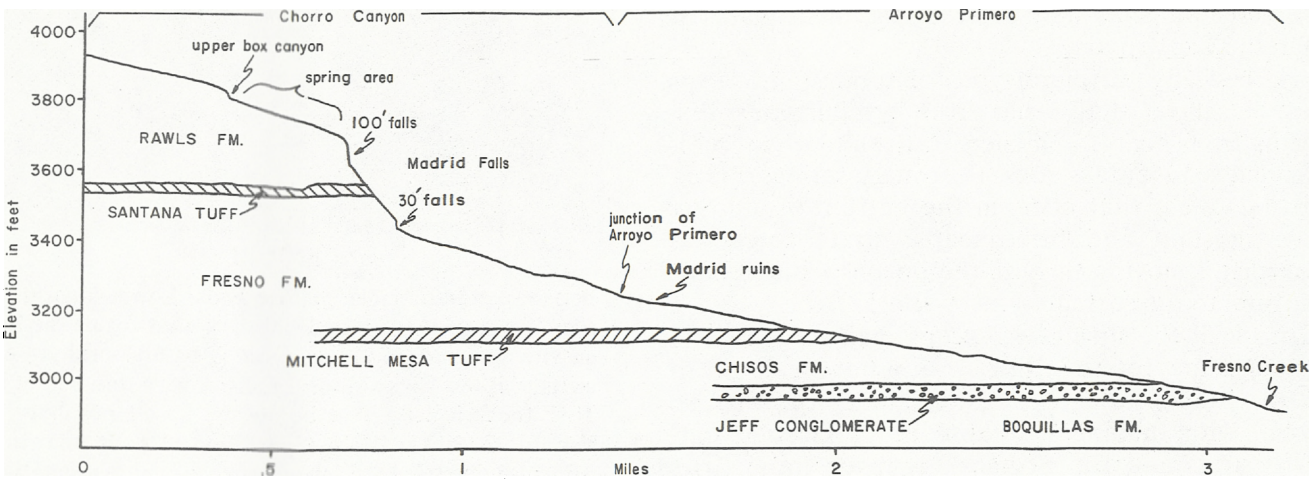

FIGURE 20

Long Profile and Geologic Section in Chorro Canyon and Arroyo Primero from above Madrid Falls to Fresno Creek. (From McKann and others 1973: Fig. 2)

FIGURE 21

Mexicano Falls in Arroyo Segundo.
Photo by Dwight Deal

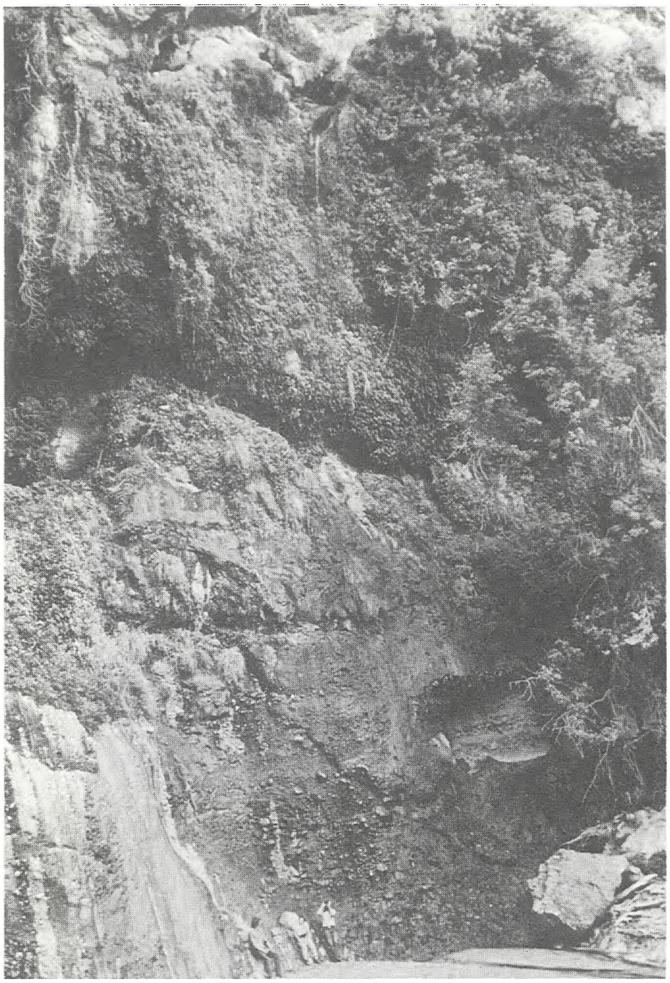

FIGURE 22

Mexicano Falls in Arroyo Segundo. Low flow (probably minimum flow) conditions in July, 1975. Note figures for scale.
Photo by Dwight Deal

FIGURE 23

Mexicano Falls in Arroyo Segundo. Moderate flow conditions in August, 1975. The night before this picture was taken a 2-meter wall of water exploded over the lip of the falls, first flushing the splash basin below and then, during the waning stages of the flood, filling it again with fresh gravel.
Photo by Dwight Deal

Mexicano to the west and Chilicote Springs to the north. These springs also issue from porous zones in the trachyandesite porphyry member of the lower Rawls Formation. Intermittent springs and seeps occur in the sandy arroyo downstream from the bedrock springs at locations where impermeable rock units force the moisture to the surface. The massive latite porphyry lava flow (Tflp) at the top of the Fresno Formation in Arroyo Segundo forces the water to the surface immediately upstream from the lip of Mexicano Falls and forms the resistant lip that holds up the falls. Flowing water usually extends several kilometers downstream from the falls, often reaching Fresno Creek. Numerous pleasant pools (Figs. 11 and 12) occur in the bed of Arroyo Segundo where there are outcrops of Jeff Conglomerate (described earlier) in the streambed.

Fresno Canyon and Fresno Falls

Springs and seeps along the length of Fresno Canyon are common from the mouth of Arroyo Segundo downstream to the Rio Grande. There is often continuous flow throughout the entire length of this reach after the summer and fall rains. Springs and seeps on the canyon walls tend to issue from bedrock, while those in the floor of Fresno Canyon are the result of the ground water in the unconsolidated sediments being forced to the surface by impermeable bedrock units. Even in the driest of seasons dependable water occurs in several places along the length of Fresno Creek. One of the locations is at the Smith Ranch ruins where water normally flows on the surface of Fresno Creek. Even in the driest years, water can dependably be obtained by digging a shallow pit in the moist gravels in the creek bed. A fairly extensive and impressive area of small springs occurs on the west wall of Fresno Canyon above the Smith Ranch ruins. These are mostly bedrock springs that derive their water from porous zones in the upper part of the Fresno Formation. At one time a pipeline system brought this water down to the Smith Ranch, and, although a segment of that pipe still exists across the bed of Fresno Creek, the pipeline system has fallen into disservice. (A more complete description of the extensive pipe system on Big Bend Ranch is given in the water resources section of the companion volume on the Bofecillos Mountains, Deal 1976b.)

Fresno Falls are a series of two cascades (Figs. 8, 9, and 10), one containing a meter-high waterfall, in the bed of Fresno Canyon immediately upstream from the junction of the mouth of Arroyo Primero. Impervious outcrops of the Jeff Conglomerate force the water to the surface at the cascades.

Another major spring area with dependable water occurs just south of the southern Big Bend Ranch fenceline. Here water collects in a large concrete trough and is locally known as "Trough Spring" (not to be confused with the "Trough Spring" marked on the Santana Mesa U.S. Geological Survey quadrangle map in the bed of Arroyo Primero above the Madrid Ranch ruins). This spring is frequently visited by residents of the Terlingua-Lajitas area who use it as a dependable source of good drinking water. Water in the Rio Grande and the shallow aquifers beneath the Rio Grande floodplain is of poor quality, both biologically and chemically. The springs are usually reached via Whitroy Mine from Lajitas.

Flash-flood Runoff

Summer and fall storms are frequently sudden and intense, often causing the major drainages in the area to run with several meters of water and debris. Camping in the bottom of arroyos and canyons can be extremely hazardous during the storm season. I was camped at the Smith Ranch ruins one evening in August, 1975, when thunderstorms far upstream and out of sight in the vicinity of Javelina Pump and Panther Mountain (Arroyo Segundo headwaters) caused the normal trickle in Fresno Canyon to rise in a matter of minutes to a depth of two meters. A year earlier unwise campers were sleeping by the side of the stream in Arroyo Segundo below Mexicano Falls (Fig. 23) and were overwhelmed by a similar flood front, causing one death. Camping beside a flowing stream is obviously attractive, especially in the otherwise dry Chihuahuan Desert, but it is particularly dangerous in the Fresno Canyon area. The intense rain that gives birth to the flash floods often occurs out of sight beyond the steep canyon walls, and the sound of the small stream usually drowns out the noise generated by the rapidly advancing front of the flash flood.

Unusual rainfall occurred in the entire Trans-Pecos area in September, 1974, and most of the major canyons in the area were severely flushed of vegetation and old flood sediment. The one canyon that did not flow disastrously happened to be Chorro Canyon. The drainage upstream from Madrid Falls is relatively small and, although larger than normal quantities of water flowed over the falls and through the canyon (Burns 1976), the vegetation in Chorro Canyon was not as severely thrashed by the floodwaters as it was in most of the other canyons in the region. In the Fresno Canyon area the tendency is for large storms to fill splash pools and swimming holes with gravel, while exceptionally large runoffs (as in September, 1974) tends to flush sediment downstream and create sizable pools. This was noticed during the time the Natural Area Survey field party was in the area. Several very large pools that were the aftermath of the 1974 flooding provided refreshing swimming holes during the summer of 1975. Most were filled with sand and gravel as a result of the flash flood mentioned earlier that occurred in August, 1975.

CONCLUSIONS

The Fresno Canyon area is an extremely interesting part of the Chihuahuan Desert and provides an unusual range of geologic, physiographic, and habitat settings within relatively short distances. The mountains in the Chihuahuan Desert portion of West Texas are typically either volcanic or limestone; the west wall of Fresno Canyon is a fine representative example of the volcanic terrain, while the east wall is typical of the limestone areas. The water resources in the canyon are unusually good, and the variety of springs demonstrates most of the types to be found in the desert. The large landslide blocks in the vicinity of the Smith Ranch ruins are outstanding examples of gravity-slide phenomena. The Shelter Thrust exposure, north of the ruins, is the finest I know that shows the toe of a small gravity-slide block. A visit to that exposure alone is worth the trip for a geology student. In addition, the canyon is aesthetically very pleasing.

Fresno Canyon is without a doubt an exceptional natural laboratory. From the standpoint of an educator in the natural sciences, this field area serves as an unusually good teaching tool. The well-exposed, varied examples of terrain, ground and surface water occurrences, the variety of faulting and folding, and the varied habitats have been altered very little by the activities of modern man. This is truly a natural area that is an important part of the heritage of West Texas. I hope that wise custodianship of the Fresno Canyon area will continue and that future generations of students and scientists will also have the opportunity to study in this exceptionally varied and relatively undisturbed natural area.

ACKNOWLEDGEMENTS

The preservation of the Fresno Canyon area in its natural state is a result of the wise management practices of Big Bend Ranch and the Diamond A Cattle Company, who not only allowed but encouraged our study of the area. The assistance of all those involved with the ranch, R. R. Anderson, R. B. Anderson, Joe Mims, Mark Davis, numerous ranch hands, and especially Ralph Hager, the ranch foreman, was greatly appreciated. Ralph was particularly generous in his help, not only providing a great deal of information about the area but supplied occasional equipment and assistance at times of vehicle malfunction, and was a source of good fellowship as well. He additionally spent several days with the field team assisting with the data gathering and the acquisition of field collections. The ranch ran its bulldozer down the Fresno Canyon road as we began to work in the area, significantly improving working conditions. I think all of the members of the Natural Area Survey field party learned to share the love and appreciation of this area held by owners and workers on the Big Bend Ranch. We are grateful to have had that opportunity.

Jack Burns and Bob Walters, science teachers at the Alpine High School, also provided significant field assistance. Rick Sohl and Bill Sohl, of Alpine, helped by making available a 4-wheel drive vehicle and radio communications that proved invaluable when the field team had two immobile field vehicles. Jack Burns also made available his 4-wheel drive truck, which turned out to be the major work-horse for our crew, and Linda Roark helped out with her Jeep. Our study was a major group effort, and many helped make it a success. We thank all of you.

The area is a difficult one to work in, especially during the hottest and driest part of the season. It is remote and rugged, and I appreciate the fine educational and cultural environment created by the rest of the study team, the students from Sul Ross State University and others that assisted the program. They all combined to make the 118° temperatures and cliffs covered with stickerbushes more bearable.

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APPENDIX 1

CRETACEOUS STRATIGRAPHY

INTRODUCTION

The rocks of Cretaceous age that are exposed in the Fresno Canyon study area are subdivided into the Lower Cretaceous (Comanche) Series and the Upper Cretaceous (Gulf) Series. The first part of this appendix (Shutup Conglomerate through Del Rio Clay) is taken, with permission, nearly word-for-word from Corry (1968:88-91 and 119-124) and the description of the younger rocks (Buda Limestone through Aguja Formation) from McKnight (1968:16-20). This appendix complements the discussion earlier in the text; reference should be made to Tables 3, 4, and 5.

LOWER CRETACEOUS (COMANCHE) SERIES

The limestones which constitute the Lower Cretaceous section are beautifully exposed in the rim escarpment of the Solitario Uplift by topography, aerial photography, and the dissection by the canyons of the Shutups. Herrin (1958) has divided the Lower Cretaceous into seven formations; however, his stratigraphic names were informal, and Maxwell and others (1967) have formally named rock units in the Big Bend National Park, correlating rock units in the Solitario. In accordance with the stratigraphic code, Corry (1972) used the formation and group names of Maxwell and others (1967) where applicable. His correlation of these rock units was based in part on the fossil correlation given in Table 4. Regional correlation of Cretaceous stratigraphy is shown in Table 3. Corry (1972:90-91) discusses his correlations as follows:

> Reasonable correlation is attained for the Glen Rose, Santa Elena, Del Rio, and Buda Formations. Herrin's (1958) informal name of Shutup Conglomerate has been retained for the basal conglomerate. Herrin's (1958) Yucca Formation has been retained, but may correlate with Smith's (1970) La Peña Formation in northern Coahuila, Mexico. Insufficient fossil assemblages were available to make correlation at the present time.
>
> The largest areas of uncertainty are the formations mapped as Telephone Canyon, Del Carmen Limestone, and Sue Peaks Formation. Insufficient fossil assemblages were available to attempt age correlations, and correlations between Big Bend National Park and the Solitario are based on stratigraphic position and lithologies.

Trinity Group

The Trinity Group was extended by Corry (1972) to include the Shutup Conglomerate, Yucca Formation, and the Glen Rose Formation. As used by Maxwell and others (1967) and Smith (1970), the Trinity Group only included the Glen Rose Formation of the three. Maxwell and others (1967) frequently refer to a basal conglomerate beneath the Glen Rose Formation but do not give it formation rank; therefore, Herrin's (1958) Shutup Conglomerate is retained. The Yucca Formation (Smith 1940; Herrin 1958:88) may be the equivalent of the La Peña Formation of Coahuila, Mexico (Smith 1970:24). The described lithologies are roughly similar, and stratigraphic positions agree, but unfortunately only one identifiable fossil, *Exogyra quitmanesis* Cragin (Herrin 1958:87), has been found in the Solitario in this formation. The Trinity Group is Upper Aptian to Lower Albian in age.

Shutup Conglomerate. The Shutup Conglomerate (Herrin:77) is the basal unit of the Cretaceous rocks in the Solitario and is the only Cretaceous rock unit which is not calcareous. The conglomerate is composed of poorly-sorted, sub-rounded material derived from the Ouachita facies rocks exposed in the central basin of the Solitario.

The Shutup Conglomerate consists of pebbles and boulders of chert and novaculite, a few fragments of limestone, sand-sized detritus, interstitial clay, and a siliceous cement. In thin section the cementing matrix is quartz with about 5% magnetite and hematite included. There is no obvious bedding. The rock weathers a characteristic deep purple hue which makes field identification a simple matter. The unit is best exposed at the upstream entrances to the Shutups. Herrin (Herrin:77) measured a section 30 m thick at the type locality, the upstream end of the Lefthand Shutup. The unit thickens and thins over the buried Paleozoic topography from a maximum of about 30 m to a minimum of about 15 m.

The Shutup Conglomerate is underlain by the angularly unconformable Tesnus Formation and overlain conformably by the Yucca Formation. The Shutup Conglomerate was undoubtedly laid down as a result of the encroachment of the Cretaceous sea across the Coahuila Platform. Herrin (1958:78) found no fossils but assigns it an age based on its stratigraphic position of Middle to Upper Aptian.

Yucca Formation. The Yucca Formation was named by Smith (1940) in the Devil's Ridge area and extended by Huffington (1943) to the Quitman Mountains. Herrin (1958:88) extends the formation to the Solitario area based on lithology as a transitional unit between basal conglomerate and overlying normal marine limestones.

Herrin's (1958:86) measured section is 210 m thick. In the lower 46 m of the section, the Yucca Formation is dolomitized. These are the only rocks in the Solitario which have significant magnesium content. Although predominantly calcareous, the limestone and dolomites contain more detrital material—sand and clay—than limestones higher in the section. The Yucca contains a few beds of shale, some yellow marl, and numerous beds of calcareous sandstone and dolomite, particularly in the lower part. In the upper part of the unit, limestones, some which are oolitic, contain less detrital material. The formation tends to weather yellow or dark red with crossbedded sandstones showing distinctive color banding.

Herrin (1958:87) assigns an age of Upper Aptian to Lower Albian. The Yucca Formation overlies the Shutup Conglomerate conformably and is conformably overlain by the Glen Rose Formation.

Glen Rose Formation. The Glen Rose Formation was first mapped in the Solitario by Sellards and others in 1931. Lonsdale (1940) and Erickson (1953) also used Glen Rose for Comanchean limestones in the Solitario. Herrin (1958) called it the Solitario Formation, but the fossil correlation in Table 4, particularly the distinctive foraminifera *Orbitolina texana* conclusively shows this to be the Glen Rose Formation (Corry 1972:121).

Herrin (1958:92) measured a section 353 m thick. The Glen Rose Formation in the Solitario consists of alternating massive limestones and thinly-bedded marly limestones. The formation is generally fossiliferous with shell beds and coquinoid layers. The Glen Rose is conformably overlain by the Telephone Canyon Formation which may be distinguished from the Glen Rose by the presence of nodular and bedded chert. The Glen Rose conformably overlies the Yucca Formation.

The Glen Rose Formation was named by Hill (1891:504) from exposures along the Paluxy River near the town of Glen Rose, Texas. The Glen Rose, of course, occurs widely in Texas and northern Mexico. Smith (1970:25) provides a good recent review of its distribution and regional variation. The Glen Rose Formation is Lower Albian in age and is the youngest member of the Trinity Group in the Solitario.

Fredricksburg Group

The Fredricksburg Group exposed in the Solitario and underlying Fresno Canyon is the same as outlined by Maxwell and others (1967:31), with the exception of the Maxon Sandstone, which has no Solitario equivalent. The group includes the Telephone Canyon Formation and the Del Carmen Limestone. The Telephone Canyon Formation includes the upper 58 m of Herrin's (1958) Solitario Formation. The Del Carmen Limestone is the lower unnamed member of Herrin's (1958) Fresno Peak Formation. Correlation is based on lithologies and stratigraphic position of the formations. The Fredricksburg group is Middle Albian in age.

Telephone Canyon Formation. The Telephone Canyon Formation in the Solitario consists of alternating one-meter-thick beds of grey fossiliferous limestone and grey, marly limestone which weathers yellow to reddish-brown. Red stains are common.

The Telephone Canyon Formation was named by Maxwell and others (1967:35) for exposures in Telephone Canyon in Big Bend National Park. Smith (1970:39) assigns an age of Middle Albian; the formation is generally correlative with the Walnut Clay of Central Texas.

The formation is conformably underlain by the Glen Rose Formation and overlain by the Del Carmen Limestone.

Del Carmen Limestone. The Del Carmen Limestone is named from the sheer escarpments of the Sierra del Carmen by Maxwell and others (1967:36). In the Solitario it is represented by the lower unnamed member of Herrin's (1958) Fresno Peak Formation; it is 209 m thick.

The Del Carmen Limestone is a massive grey limestone which weathers to shades of brown. Large chert nodules and lenticular bodies are common. Rudistids are common. The Del Carmen Formation is conformably underlain by the Telephone Canyon Formation and grades upward into the overlying Sue Peaks Formation. The age is indeterminate because of a lack of identifiable fossils, but the Del Carmen is probably Middle Albian in age.

Washita Group

Corry defines the Washita Group exposed in the Solitario the same as did Maxwell and others (1967). Four formations are included in this group in the Solitario: the Sue Peaks Formation, Santa Elena Limestone, Del Rio Clay, and Buda Limestone. Correlations of the Buda Limestone and the Del Rio Clay are well established. Correlations between Herrin's

(1958) Blue Range Formation and Maxwell and others (1967) Santa Elena Limestone is based on stratigraphic position, lithology, and the fact that both authors refer to the formation as the local Georgetown equivalent. An attempt at fossil correlation (Table 4) by Corry (1972) was inconclusive due to incomplete collections from the separate areas. The Washita Group ranges in age from Middle Albian to Lower Cenomanian.

The formation is characterized, in the Solitario, by massive limestone beds, rudistid bioherms, and thin-bedded chert. A distinctive maker bed of interbedded chert and sandy limestone occurs from 64 to 72 m above the base of the Santa Elena Limestone and can be recognized in all exposures in the rim of the Solitario.

The Santa Elena Limestone rests conformably on the Sue Peaks Formation and is conformably overlain by the Del Rio Clay which represents a sharp lithologic break at the contact. The age of the Santa Elena Limestone is Upper Albian.

Sue Peaks Formation. The Sue Peaks Formation was named by Maxwell and others (1967:40) from the Sue Peaks in the Sierra del Carmen. This is the Marly Member of Herrin's (1958) Fresno Peak Formation and is approximately 57 m thick in the Solitario.

The rock is marly and weathers a characteristic yellow. The base of the Sue Peaks Formation is gradational into the Del Carmen Limestone. It is conformably overlain by the Santa Elena Limestone. Smith (1970:42) assigns an age of uppermost Middle Albian to the Sue Peaks Formation in this region.

Santa Elena Limestone. The Santa Elena Limestone was named by Maxwell and others (1967) from the rocks forming the upper half of the sheer canyon walls at the mouth of Santa Elena Canyon in Big Bend National Park. The Santa Elena is the local equivalent of the Georgetown Limestone of Central and Southwest Texas. Herrin (1958) called this the Blue Range Formation and in the Solitario measured a section 250 m thick.

Del Rio Clay. The Del Rio Clay along the eastern side of the Fresno Canyon area is similar in stratigraphic position, lithology, thickness, and fossil content to the Del Rio at its type locality. Herrin (1958) measured a section 38 m thick in the Lefthand Shut-up of the Solitario.

The Del Rio Clay consists of grey to green marl and shale which weathers greyish-yellow. Thin flaggy beds of red sandstone and siltstone are common, as well as pyrite and gypsum.

The Del Rio is conformably underlain by the Santa Elena Limestone and overlain by the Buda Limestone. The age of the Del Rio Clay is Lower Cenomanian.

Buda Limestone. The Buda Limestone is exposed along the east side of Fresno Canyon on the flanks of the Solitario. Vaughan (1900:18) applied the name "Buda" to replace the preoccupied "Shoal Creek Limestone" of Hill (1889:xxiii-xxiv); the type locality is along Shoal Creek in Austin, Texas. This limestone has been traced with nearly continuous exposure into Trans-Pecos Texas. It is exposed as the caprock of a hogback on the west side of the Solitario and also in an isolated klippe, 60 m long forming the upper plate of the Shelter Thrust in Fresno Canyon. The 21-m-thick Buda is poorly-bedded to massive, nodular white micritic limestone; fossil molluscs are rare, and other phyla are absent. The contact with the underlying Del Rio Clay is covered; Moon (1953) reported a possible diastem between the two formations in the Agua Fria Quadrangle, several kilometers northwest of the head of Fresno Canyon. The contact with the overlying Boquillas Formation is abrupt and perhaps disconformable. An undulating surface at the top of the Buda has about 15 cm of relief in about a meter of laterally exposed contact; it is overlain by well-bedded, buff, flaggy limestone of the Boquillas Formation.

UPPER CRETACEOUS (GULF) SERIES

The section of Gulf strata in Fresno Canyon is a gradational sequence which may be divided lithostratigraphically into three parts: a lower part of interbedded limestone and clay, a middle clay, and an upper part of interbedded sandstone and clay. Stratigraphic nomenclature of this section has been progressively redefined by successive workers (Table 5).

Udden (1907) divided the section into three formations. His Boquillas Flags included the lower half of the interbedded limestone and clay and was capped by the Crioceras zone—a prominent brown-weathering sandy limestone bed about one-half-meter thick that contains *Allocrioceras hazzardi*, a distinctive uncoiled ammonite, also found near the top of the Eagle Ford in Central Texas. Udden's second unit, the Terlingua beds, included the upper part of the interbedded clay and limestone zone and the clay zone; his Rattlesnake beds included the interbedded sandstone and clay beds at the top of the section.

Adkins (1933) restricted the name "Terlingua" to the lower interbedded limestone and clay and applied the name "Taylor" to the clay and the lowermost part of Udden's Rattlesnake beds. The name "Rattlesnake" was discarded because of prior usage, and the name "Aguja" was applied to the rest of the sandstone and clay section. The names "Boquillas," "Ter-

Table 5 – Nomenclature used by various workers in the Big Bend Region, Texas, for Upper Cretaceous Formations. (From McKnight 1968: Fig. 5)

Approximate Thickness (feet)	Lithology	Udden (1907)	Adkins (1933)	Yates and Thompson (1959)	Maxwell and others (1967)
1500	sandstone and clay	Rattlesnake Beds	Aguja Formation	Aguja Formation	Aguja Formation
	clay	Terlingua Beds	Taylor Clay	Terlingua Clay	Pen Formation
1000	clay and limestone	Terlingua Beds	Terlingua Beds	Upper Boquillas Flags (Boquillas Formation)	San Vicente Member (Boquillas Formation, Terlingua Group)
500	Crioceras zone				
	flaggy limestone	Boquillas Flags	Boquillas Flags	Lower Boquillas Flags (Boquillas Formation)	Ernst Member (Boquillas Formation, Terlingua Group)
0					

lingua" (restricted), "Taylor," and "Aguja" were thus correlative, as nearly as could be determined, with Eagle Ford, Austin, Taylor, and Navarro of Central Texas.

Yates and Thompson (1959) divided the section into three units: their Boquillas Flags included all of the limestone and clay section, the name "Terlingua" was applied to the clay section, and "Aguja" was extended downward to include all of the sandstone and clay section. They divided the Boquillas into upper and lower members on the Crioceras zones. Their lower member was equivalent to the entire Boquillas of Udden and Adkins.

Maxwell and others (1967) used the same formation boundaries as Yates and Thompson but substituted the name "Pen" for "Terlingua"; the Terlingua was elevated to group status to include the Boquillas which was then divided into the Ernst Member (below) and the San Vicente Member (above). The contact between these two members is a diastem a meter or so above the Coilopoceras (Ammonite) zone which is above the Crioceras zone and also present in the Eagle Ford of Central Texas. They correlated the Ernst Member with the Eagle Ford Group of Central Texas, the San Vicente Member with the lower part of the Austin Group, the Pen Formation with the Dessau and Burdett Formations of the Austin Group, and the Aguja Formation with the lower part of the Taylor Group.

Although the nomenclature in this report follows the usage of Maxwell and others (1967), the Boquillas is not subdivided into members on McKnight's (1970) map; thus, the contacts are consistent with those of Yates and Thompson.

Boquillas Formation. The Boquillas Formation (Maxwell and others 1967) is exposed along the eastern and southern parts of Fresno Canyon in the erosional lowlands. McKnight (1968:19) reports small outcrops in an up-faulted block near the western edge of the Bofecillos Mountains and in Rancherias Dome, west of Fresno Canyon, which indicates that the Boquillas probably underlies all of the Bofecillos volcanic field.

The Boquillas Formation is composed of interbedded calcareous clay and thin-bedded argillaceous micritic limestone. Some of the limestone beds are sandy or silty. Unweathered surfaces of the limestone and shale are gray to black; the rock weathers cream-white, yellow, or buff-brown. The percentage of shale increases up the section: the lower beds are almost entirely limestone; the upper half of the formation is mostly shale. In the lower part of the Boquillas, clay partings cause the limestone to break into thin flaggy plates; in the upper part chalky limestone is interbedded with marly clay.

Because the Boquillas is extensively faulted, its total thickness in this area is difficult to determine accurately. Erickson (1953) estimated that the thickness in the Tascotal Mesa Quadrangle is about 180 m; Yates and Thompson (1959) estimated a thickness of about 300 m in the Terlingua District.

The Boquillas contains abundant fossils, particularly *Inoceramus, Ostrea,* Foraminifera, and Ammonites.

As a consequence of the greater percentage of clay, the upper part of the Boquillas is, in general, less resistant to erosion than the lower part. Where tilted, the resistant limestone beds of the Boquillas commonly form a series of cuestas; where flat-lying, the hillside profiles are characterized by stair-stepped ledges.

The contact between the Boquillas and the overlying Pen clay is gradational. The upper beds of the Boquillas are progressively thinner and shaly. Limestone beds are chalky and the ledges progressively less prominent. McKnight (1968, 1970) located the contact immediately above the highest limestone bed that is perceptible from a distance of about 15 m. From this distance the contact looks moderately distinct. Although the choice of the highest preciptible bed is dependent on several variables, particularly steepness of slope and dip of beds, the contact so chosen is probably located consistently within a two-meter stratigraphic interval throughout the part of the map area where the contact is exposed. The Boquillas is thus characterized by limestone beds and the Pen by non-bedded clay and marl.

Pen Formation. The Pen Formation (Maxwell and others 1967) is exposed in the Contrabando and Lajitas lowlands south of the Fresno Canyon study area and in Rancherias Dome to the west. It is about 60 m thick. Fresh outcrops of Pen are gray, but weathered surfaces are yellow or buff. Bedding is visible only on unweathered surfaces or where the clay was baked by nearby intrusions. The Pen forms smooth slopes except for thin ledges of limestone near the base, visible from a distance of several meters or more and reflecting the gradational nature of the lower contact. The clay commonly exhibits a "popcorn" weathering surface and is probably montmorillonitic. Some parts of the Pen are gypsiferous. *Inoceramus* is sporadically abundant near the base.

The Pen is less resistant to erosion than the underlying Boquillas and the overlying Aguja; it normally forms a lowland belt of rounded hummocky topography between the two resistant formations. The Pen-Aguja contact is gradational; it is placed immediately beneath the lowest sandstone bed that is conspicuous from a distance of about 15 m. Thus, defined, it is probably within a 2-m stratigraphic interval.

Aguja Formation. The Aguja Formation (Yates and Thompson 1959) is present south of the study area in a 450- by 900-m exposure on the south flank of Contrabando Dome. Maximum thickness is probably not much greater than 20 m. The Aguja consists of interbedded gray to gray-green and brown sandstone and shale. The maximum thickness of individual sandstone beds is about 30 cm; most beds are less than 10 cm thick. Some of the thicker sandstone beds are cross-bedded.

A few lignite seams are present in the exposure; all are less than 3 cm thick. The Aguja contains abundant fossils, most of which are pelecypods including *Ostrea,* some *Inoceramus,* and a few rudistids.

Beds of Aguja in the area are flat lying or gently dipping. Abundant thin beds of sandstone form weak ledges on slopes.

APPENDIX 2

ORIGIN OF THE TERLINGUA-SOLITARIO MONOCLINE
(modified from Corry 1972:74-76)

Most of the recent literature (Maxwell and others 1967) refers to this feature as the Terlingua-Solitario Monocline. The appearance of the ridges on opposite sides of the axis of the structure, as seen on aerial photographs, led Corry (1972) to refer to this structure as an anticline. He continued:

> The axis of the anticline is characterized by normal faults which strike perpendicular to the anticline axis. These faults bound at least one graben whose axis is also perpendicular to the axis of the anticline. This graben is obviously the result of longitudinal extension of the anticline. With the conjunctive relation of the anticline to the Solitario, two hypotheses can be advanced to explain the origin. The first hypothesis is an anticlinal laccolith, and the second, a broad open-folded doubly-plunging anticline, resulting from compression from the southwest as a result of Laramide deformation. In either case it is believed that the formation of the anticline postdates the formation of the Solitario dome. This conclusion is based on the circular shape of the Solitario. If the broad anticline had predated the Solitario, the zone of weakness in the anticline would have made the Solitario a more elliptical feature. In addition, it appears that intrusive and extrusive phases of the Laramide predate the compressive phase in this area.

Corry (1972:75) assumed that the crest of the structure exposes what must be nearly the top of the Santa Elena Limestone, and on that basis estimated the structural relief (uplift) to be about 0.5 km.

While the observed throw of 0.5 km is within the range of deflection calculated by Corry for theoretical laccoliths and observed for laccoliths in the Henry Mountains, this structure is certainly much larger. The Terlingua-Solitario Monocline is approximately 20 km long by 12.5 km wide, dimensions more typical of compressive deformation which would be associated with late Laramide mountain-building activity. Corry (1972:75-76) continues:

> Without further evidence, the interpretation of the anticline as a compressional feature of late Laramide deformation would be unquestioned. However, the presence of extensive cinnabar deposits, associated with the formation of the anticline, which are of definite magmatic origin (Baker 1935), make it unlikely that the uplifts is of purely compressive origin. In view of the cinnabar deposits, which occur throughout the anticline, it is believed that an intrusive laccolithic body must be responsible for the anticline. The literature in general (West Texas Geol. Soc. 1965) has long favored an intrusive body beneath the anticline for the reasons cited above.

The depth of the intrusive body must be on the same order as the body forming the Solitario, namely 1.5 km to 2.0 km. The Cretaceous beds acted, apparently, as the resistant beds during intrusion. The steep flanks are apparently formed by the same process of drape folding (Stearns 1971) that formed the flanks of the Solitario. Because deflection was only on the order of 0.5 km, extentional effects have not played as important a role as in the Solitario. The crestal grabens have formed perpendicular to the axis of the anticline, as a result of the doubly-plunging shape of the domed strata above the laccolith.

APPENDIX 3

THE TERLINGUA MERCURY DISTRICT

(from Daugherty 1972)

The Terlingua Mercury District has been one of the most important sources of mercury mined in the United States. The total production from this district is more than 150,000 flasks of 76 pounds each and constitutes about one-fourth of the total production of the United States. The district is a narrow east-west belt which extends from Study Butte on the east to the Fresno mine area on the west, a distance of about 30 km (Fig. 7). Numerous occurrences of mercury mineralization are known outside the accepted limits of the Terlingua Mercury District, but the only noteworthy production outside the district has been obtained from the Mariscal or Lindsey Mine in the southern part of Big Bend National Park about 40 km southeast of Study Butte. The most comprehensive description of the Terlingua Mercury District was provided by Yates and Thompson (1959) from whom some of the following information has been extracted.

The date and location of the first discovery of mercury mineralization in the district is unknown, but it is locally believed that the presence of cinnabar, the red sulfide of mercury, was known to the Indians who collected it for use as a pigment. The first authenticated production from the district began in 1894 to 1895 near California Hill, located 8 km west of the abandoned mining town which now bears the name Terlingua. By 1898 there was a settlement near California Hill large enough to justify establishment of a post office which was named Terlingua. Discovery of rich ore in 1900 near the present-day Terlingua led to development of the Chisos Mine in 1902. A decline in production from the area around California Hill in the first years of this century resulted in a shift of population eastward to the newly-discovered Chisos Mine. This ultimately led to the transfer of the post office and the name Terlingua to the new settlement. Following the shift of the name Terlingua from its original location, the California Hill area was renamed Mariposa.

The 248 and Study Butte Mines in the eastern part of the district were discovered in 1902. Development during World War II of the Fresno Mine extended the district to its present western limit about 13 km northwest of Lajitas. The most recent discovery was made in 1966 adjacent to the Fresno Mine and resulted in the development of the Whitroy Mine.

The principal early production from the district was furnished by the Mariposa Mine and totalled approximately 20,000 flasks by 1905. Production from the Mariposa Mine declined after the turn of the century and was suspended in 1910. From that date until World War I the Chisos Mine was virtually the only mine producing in the district. The war-occasioned increase in mercury prices, from an average of $47.50 per flask in the 1905-1915 period to an average of $118 per flash in the 1916-1918 period, led to a revival of operations at the older and smaller mines in the district. A rapid decline in mercury prices immediately following World War I led to a suspension of activities at all mines except the Chisos.

During the late twenties and thirties several new mines were developed, and, on several occasions, old mines were reopened for brief periods, but the Chisos Mine was the only mine to produce continuously during this time. The beginning of World War II resulted in increased activity in the district with the development of new mines and the resumption of activities in several of the old mines. A post-war decline in mercury prices led to the complete cessation of mining activities in 1947, and from that time until the present the district has experienced only brief flurries of prospecting and mining activities separated by longer periods of inactivity. As might be suspected, the rise and fall of the fortunes of mercury mining in the district corresponded closely to fluctuations in mercury prices which, in the post-war period, ranged from a high of $725 per flask in July, 1965, to a 22-year low of $145 on April 26, 1972.

In early 1971 three mines, the Study Butte, Fresno, and Whitroy mines were still in operation, but by the end of the year all activity ceased in the district as a result of a long-continued decline in mercury prices.

The structure of the Terlingua Mercury District is dominated by a northwest-trending Terlingua Uplift, an elongate asymmetric anticlinal fold bounded on the west and south by the Terlingua Monocline and on the east by the Long Draw Graben. The Terlingua Uplift has a structural relief of several thousand feet and culminates to the northwest in the Solitario Dome, a high symmetrical structure in whose core are exposed highly-folded and thrust-faulted Paleozoic rocks of the Ouachita Fold Belt. The origin of the Terlingua Uplift is uncertain but has been ascribed to the intrusion of magma at depth and to the effects of Laramide compression. The Solitario Dome, according to Lonsdale (1940), resulted from the laccolithic intrustion of magma.

The regional structure of the Terlingua Uplift has been complicated in many places by a number of smaller structures superimposed upon it. These structures include laccolithic domes, steeply-dipping northwesterly-trending normal faults which form grabens, and breccia pipes or "sinks." Two persistent sets of steeply-dipping joints are evident in the district. The northwest set includes most of the major faults, but the northeast set is usually the most persistent and is often mineralized.

Rocks exposed in the Terlingua District consist of Cretaceous sedimentary and Tertiary hypabyssal intrusive rocks. The Cretaceous sedimentary rocks, in ascending order, include: massive chert-bearing Santa Elena Limestone (300+ m), Del Rio Clay (25-60 m), Buda Limestone (15-30 m), Boquillas Formation (about 330 m of flaggy limestone and marl), Pen Formation (approximately 300 m of dark marl and clay that weathers yellow), and Aguja Formation (about 250 m of sandstone and clay with some lignite in the upper part). The intrusive rocks in the form of stocks, sills, laccoliths, and dikes are sodic and range in composition from rhyolite to basalt.

The principal mercury mineral is cinnabar, the red mercury sulfide. Much less common is native mercury and metacinnabarite, the black sulfide of mercury. The Mariposa Mine area is noted for its great variety of rare mercury minerals which include colomel ($HgCl$), eglestonite (Hg_4Cl_2), kleinite and mosesite (complex ammonium chlorides), montroydite (HgO), and terlinguaite (Hg_2ClO). The principal gangue mineral is calcite, but others present include aragonite, marcasite, pyrite, quartz, fluorite, hematite, gypsum, kaolinite, alunite, and jarosite. Some asphaltic hydrocarbons are present in minor quantities in most of the mines.

In spite of the fact that the theory of the anticlinal accumulation of mercury deposits has long been applied to the Terlingua Mercury District, there is no obvious relationship between structurally high areas and mercury mineralization in the district. Moreover, no district-wide control of mercury mineralization is apparent. The Terlingua Uplift, the dominant structure in the area, does not control the distribution of mercury mineralization, for the narrow east-west belt of productive mines lies athwart of the uplift and extends beyond its boundaries (Fig. 13). The mercury mineralization at each mine seems to be controlled by minor structures independent of the regional structure. The principal mineralization occurs as veins cutting sedimentary and intrusive igneous rocks, as stratigraphically controlled tabular deposits or "mantos," and as open space fillings in rubble-filled solution caverns and breccia pipes.

The most common and most important deposits in the district occur at or near the Santa Elena Limestone-Del Rio Clay contacts, especially where solution of the underlying limestone allowed clay to collapse into the solution cavities to form "cave-fill" deposits. Examples of ore bodies of this type include the Chisos, Mariposa, and Fresno mines.

The best examples of vein fillings are at the Chisos, 248, and Study Butte mines. At the first two mines early production was obtained from steeply-dipping, northeasterly-trending calcite veins in the Boquillas Formation. The deposits at the Study Butte Mine consist mostly of near-vertical veins cutting the 12-m-thick quartz-poor, sodic rhyolite sphenolith, or wedge-shaped sill, which has been emplaced in the Pen Formation.

Some mercury mineralization is found as open space fillings in breccia pipes. These pipes have diameters of as much as 150 m and are known to extend to depths of more than 250 m. The nature of the material filling the pipes indicates they formed by collapse of incompetent rocks into underlying cylindrical solution cavities. The most notable breccia pipe is the 248 pipe which has been more thoroughly explored than any other in the district. The pipe is circular and has a diameter of about 45 m at the surface; at the 125-m level it is elliptical and has a maximum dimension of 60 m. Unfortunately, the outcrop of this breccia is now concealed beneath the dump of the 248 mine. The pipe was explored by drifts driven at various levels from the 260-m-deep shaft. At the surface the pipe cuts flaggy limestones of the Boquillas Formation. The contact of the Santa Elena Limestone and the Del Rio Clay is encountered at a depth of 245 m in the shaft. The breccia filling the pipe consists of randomly-oriented angular blocks and fragments of various sizes. It consists of fragments of the Boquillas Formation on the upper levels, a mixture of Boquillas and Buda rocks at lower levels, and at the lowest level includes Del Rio Clay as well as rocks of the Buda and Boquillas formations. Most of the mineralization occurs in intensely-brecciated materials near the margins of the pipe. The cinnabar occurs as coatings on the surfaces of calcite-cemented breccia fragments or, where a clayey matrix is present, as impregnations in the clay. Many of the open spaces in the breccia contain appreciable quantities of asphaltic tars and, in the upper levels, considerable anacline.

The only economic body of mercury ore occurring in a breccia pipe was mined from a concealed pipe in the Chisos Mine. This vertical pipe was cylindrical in form with a diameter ranging from 10 to 20 m. The breccia in the pipe consists of fragments of the Boquillas, Buda, and Del Rio formations which may have moved downward more than 46 m. The pipe ore body consists of exceptionally high-grade cinnabar that extends from the 180-m level to the 245-m level. The cinnabar occurs as filling of open spaces in breccia in the upper part of the pipe and as a replacement of the clayey matrix of the breccia in the lower levels.

According to Yates and Thompson (78-83), the mercury deposits of the district were deposited at shallow depths from ascending alkaline hydrothermal solutions of igneous origin at temperatures of less than 300°C. They proposed that the mineralizing fluids had both gaseous and liquid phases and that the mercury was transported in a saturated solution accompanied by additional colloidal mercury.

The pyrometallurgy of mercury from cinnabar is simple. Heating to 580°C causes a rapid dissociation of mercury vapor, and the condensation of this vapor provides liquid mercury. The first reduction plants in the Terlingua Mercury District made extensive use of retorts. These retorts consisted of metal tubes enclosed in a brick fire box. A pipe from the rear end of the retort tube conducted the gases outside to cool and the liquid mercury which dropped or trickled from the end of the condensing pipe was caught in a trough. The other end of the retort tube extended to the front of the fire box where it was charged with ore and then sealed with a metal disc luted with clay. Although retorts are cheap and easy to construct, they could profitably treat only high-grade ore. Each tube in a retort was charged with approximately 225 kilos of ore and the need to allow the retort to cool sufficiently between batches of ore resulted in poor thermal efficiency and low capacities.

The first continuous furnaces used in the Terlingua District were Scott furnaces which consisted of vertical shafts constructed of bricks with a fire box at the base of the shaft. Ore was dumped into the shaft and as spent rock at the bottom of the shaft was withdrawn by a worker with a hoe, the ore descended under the influence of gravity. The flue gases were conducted by pipes of sewer tile to a series of condensing chambers constructed of brick. The thermal efficiency of this type of furnace is relatively high, but the capacity is low, and production from newly-constructed furnaces was small until the pores of the brick condenser chambers became saturated with mercury. Few furnaces of this design remain intact, because it is usually quite profitable to run the bricks through another furnace to extract the entrapped mercury.

The Scott furnaces were supplemented by mechanical furnaces of two types. The first type was the Herreshoff furnace, a stationary multiple-hearth cylindrical furnace that has the external appearance of a steel tank mounted on legs. Crushed ore is fed to the top of the furnace by conveyor belts to the upper hearth where it is raked by mechanical rabble arms in a circular path from the periphery of the furnace to the center where it falls through a hole to the next lower hearth and so on until the spent rock is discharged at the bottom of the furnace. The rotary furnace is the most popular furnace in use at the present. It consists of an inclined rotary kiln, similar to a cement kiln, that has a fire box at the lower end and a feeder at the upper end. Ore travels slowly down the inclined rotating tube and is discharged at the lower end. Both types of furnaces use vertical metal or tile-condensing systems.

The 100-ton-per-day rotary furnace at the Study Butte Mine is an excellent example of a modern rotary furnace and, because of growing concern about the dangers of mercury pollution, may be one of the last mercury furnaces to be built in the United States. The Environmental Protection Agency (EPA) established in 1972 new regulations directed at all mercury furnaces where gas emissions are sent through cooling systems to eliminate the loss of mercury vapor to the atmosphere. If the new controls prove to expensive to implement, a possible alternative is the hydrometallurgical extraction of mercury. The process involves solution of mercury sulfide in a sodium sulfide-sodium hydroxide solution and precipitation as an adherent coating on aluminum shavings. Although the chemistry of this process has been known for many years and costs are estimated to be in the range of those utilizing conventional methods, it has not yet been successfully applied to a commercial operation.

The uses of mercury are many and varied but water pollution and poisoning of wildlife and humans by mercury have led to regulatory limitation and, in some case, banning of certain uses of mercury. As a single example, the chlorine industry has consumed approximately 23% of the mercury used in the United States in the past few years. In the manufacture of chlorine, mercury acts as a catalyst in the electrolytic separation of sodium and chlorine from brine. Waters discharged into rivers and lakes from chloride plants have been found to contain low concentrations, but nevertheless significant, quantities, of mercury and, rather than install expensive pollution control equipment, chlorine manufacturers are switching to alternate methods that do not require mercury. To illustrate the declining use of mercury for this purpose, the chlorine industry used 20,720 flasks in 1969, 15,000 flasks in 1970, and only 12,350 flasks in 1971.

The future of the Terlingua Mercury District is uncertain. Few of the old mines possess visible mercury mineralization and, of those that do, none have in sight material that is presently ore in the classical sense of the term (i.e., mineralized rock capable of being worked at a profit). It is the writer's personal conviction, however, that the district still has a considerable potential for the production of mercury. This conviction is based, in part, upon the knowledge that all of the productive mines, except two, were discovered on the outcrop—and these two could have been discovered by a careful and skillful prospector, for mineralization was later found at the surface at both mines. Additionally, the writer believes that it would be extremely fortuitous if the present level of erosion were everywhere deep enough to expose all mineralized zones in the district. Exploration and development in the district, however, must await considerably higher prices for mercury before any substantial expenditures are warranted, and even that appears to be unlikely in the immediately foreseeable future when one considers the decline in the demand and uses for mercury.

APPENDIX 4

MEASURED GEOLOGIC SECTION

Measured up east-facing cliff in Fresno Canyon, about two miles west of Fresno Mine on July 5, 1964, with hand level and six-foot steel tape, by John McKnight (1968, measured section number 4, 159-161).

SUMMARY:	FEET	FEET
Rawls Formation, Member 1, Trlb		23
Santana Tuff, Ts		14
Fresno Formation		
undifferentiated, Tf	33	
trachyandesite, Tfa	115	
undifferentiated, Tf	81	
Total:	229	229
Mitchel Mesa Tuff, Tmm		25
Chisos Formation		
covered	8	
Tule Mountain Member, Tctm	176	
undifferentiated, Tc	544	
Total:	728	728
Jeff Conglomerate, Tj		16
Boquillas Formation, Kbo		11
Total measured thickness:		1,046

Unit	Description	Thickness in Feet
RAWLS FORMATION, Member 1, Trlb		
20.	Basalt. Black with red-brown specks of iddingsite; weathers brown; thoroughly weathered above lower five to seven feet to a rubble of pebble- and cobble-size fragments; probably two flows, the upper one mostly eroded. Number 1 basalt exposed about 200 feet to west consists of several more flows than are present here; probably the higher flows were removed by erosion.	23
SANTANA TUFF, Ts		
19.	Tuff. Nonwelded vitric to vitric-crystal tuff with glassy crystals of sanidine and quartz; porcelaneous; dark-red-brown; probably two ash flows of about equal thickness, because tuff near center is less indurated than above and below.	14
FRESNO FORMATION		
undifferentiated, Tf		
18.	Conglomerate. Angular and rounded pebble- to boulder-size fragments of aphanitic igneous rock in a matrix of calcite-cemented tuffaceous sandstone.	33
trachyandesite, Tfa		
17.	Trachyandesite. See description in text.	115
undifferentiated, Tf		
16.	Tuff. Festoon cross-bedded; pale-gray; some grades to festooned tuffaceous sandstone.	59
15.	Tuffaceous sandstone. Faintly thin-bedded; white to pale gray.	22
MITCHELL MESA TUFF, Tmm		
14.	Tuff. Nonwelded vitric-crystal tuff with glassy, chatoyant crystals of sanidine; middle part is slightly porcelaneous, the rest is dull and porous; forms cliff; pinches out 300 feet to south.	25

CHISOS FORMATION		
13.	Covered. Probably gray tuff—the principal constituent of float.	8
Tule Mountain Member, Tctm		
12.	Trachyandesite porphyry. Corroded plagioclase phenocrysts in a red-brown groundmass that is partly green from celadonitic alteration products; lower half forms steep slope; upper 10 feet is thoroughly weathered and yellow-brown.	176
undifferentiated, Tc		
11.	Tuff. Nonbedded to faintly-bedded; variegated white and pink.	72
10.	Tuffaceous sandstone. Thin- to medium-bedded; white with red-brown streaks along bedding planes.	53
9.	Sandstone and conglomerate. Intercalated in lenses and layers mostly less than a foot thick; sandstone is tuffaceous and thin-bedded; conglomerate is pebble-size fragments of aphanitic igneous rock in a matrix of tuffaceous sandstone.	5
8.	Conglomerate. Pebble- to boulder-size rounded and angular fragments of aphanitic igneous rock with interstitial calcitic tuffaceous sandstone.	19
7.	Tuff. Nonbedded; pink.	9
6.	Tuff. Nonbedded; white to pale-gray.	70
5.	Tuff. Faintly-bedded; white to pale-gray, with sparsely distributed pink spots as much as one foot across.	70
4.	Tuff. Nonbedded; white to gray.	98
3.	Tuff and sandstone. About two-thirds is nonbedded buff, gray, and pink variegated tuff; the rest is gray-green to red-brown tuffaceous sandstone in beds and lenses as much as five feet thick.	148
JEFF CONGLOMERATE, Tj		
2.	Conglomerate. Rounded pebbles and cobbles of micritic and cherty limestone in a matrix of calcite-cemented tuffaceous sandstone.	16
BOQUILLAS FORMATION, Kbo		
1.	Limestone. Thin-bedded, flaggy, cream-colored, micritic limestone with a few thin interbeds of pale-brown clay.	11
	Total measured thickness:	1,046

Base of section in terrace gravel covering Boquillas Formation.

A VEGETATIONAL SURVEY OF THE FRESNO CANYON AREA

Mary Butterwick and Stuart Strong

INTRODUCTION

Fresno is a Spanish name for ash, which is commonly found in the arroyos and scattered along the streambed of Fresno Creek. Probably more abundant at one time, the ash have been extensively used by man as lumber and fuel for mining operations in the area. Ash often grows in association with Arizona cottonwood (*Populus arizonica*), Southwestern black willow (*Salix gooddingii*), scrub oak (*Quercus pungens*), and Mexican blue oak (*Quercus oblongifolia*).

The most spectacular areas, aesthetically and botanically, are Chorro Canyon and Arroyo Segundo, both of which feature waterfalls and perennial pools that support a lush vegetation. Moist walls of the canyons are lined with maidenhair fern (*Adiantum capillis-veneris*), monkeyflower (*Mimulus glabratus*), stream epipactis (*Epipactis gigantea*), columbine (*Aquilegia chaplinei*), and wild rye (*Elymus virginicus*). The quiet pools nurture numerous grasses, sedges, horsetail (*Equisetum laevigatum*), cattail (*Typha latifolia*), brook weed (*Samolus cuneatus*), water hyssop (*Bacopa monnieri*), and wild petunia (*Petunia parviflora*). All these species are survivals from a time when a moist climate prevailed, and in their isolated wet habitat they have not needed to adapt to the surrounding desert conditions.

In contrast to the fecund oases, the vegetation of the slopes and flats is typical of the Trans-Pecos region with several taxa in common with those found in the Solitario. Creosote (*Larrea tridentata*), mesquite (*Prosopis glandulosa*), spiny hackberry (*Celtis pallida*), lotebush (*Ziziphus obtusifolia*), guayacan (*Porlieria angustifolia*), and ocotillo (*Fouquieria splendens*) are common in the Fresno Creek area.

Likewise, there is considerable overlap in herbaceous species, particularly the cacti, grasses, and composites such as bluntscale bahia (*Bahia pedata*), hairy seed bahia (*Bahia absinthifolia*), common dogweed (*Dyssodia pentachaeta*), *Zexmenia brevifolia*, and *Machaeranthera scabrella.* Lechuguilla (*Agave lechegilla*), candelilla (*Euphorbia antisyphilitica*), leatherstem (*Jatrapha dioica*), and sotol (*Dasylirion texanum*) are also frequently encountered.

METHODS

The plants of Fresno Creek were surveyed by two methods. First, the qualitative nature of the flora was determined by a collection of plant specimens throughout the major areas associated with Fresno Creek. Identifications of the species were made according to the *Manual of the Vascular Plants of Texas* (Correll and Johnston 1970) and the *Manual of the Grasses of the United States* (Hitchcock 1950), with the exception of the oaks which were annotated by Dr. C. H. Muller. Specimens collected have been stored at the University of Texas Herbarium for future reference.

Secondly, the composition of the vegetation was measured quantitatively. Four areas were chosen as a sample of different environmental forms: ridge top, igneous and limestone slopes, and alluvial flats. In three of the sample areas, the quadrat plot method was used according to the procedure described by Curtis and Cottam (1965). A 0.1-m quadrat (a rectangular metal frame) was placed along a 100-m tape at 10-m intervals. At each interval, the number and percentage ground cover of each plant species falling within the quadrat was recorded. The 100-m tape was then moved 10 m to the side to form a parallel line and the procedure was repeated. Additional lines were run until no new species were encountered. From this data it was possible to calculate the numerical frequency of each species, ground area covered by all plants, relative frequency, and relative dominance among the species (Appendix 2).

Extensions of the alluvial gravel near the creek bed included a narrow zone of denser shrub cover. Here a line transect was employed; a record was made of the number of individual plants of each species and the area along a 100-m tape covered by each individual. This process yields similar information, i.e., relative density, total coverage, and relative dominance of the species encountered.

DISCUSSION

The Big Bend country, with its unique and unusual life forms, has attracted the attention of botanists since the middle of the 19th century. Charles Wright made extensive botanical collections throughout the Southwest between 1849 and 1852, thus becoming the first contributor to our knowledge of the vegetation of this region. Shortly afterwards, John Torrey (1858) wrote the "Botany of the Boundary" in conjunction with the United States-Mexican boundary survey. Following the turn of the century, William Bray (1905) and Mary S. Young (1914), both professors at the University of Texas, wrote descriptions of the ecology and vegetation characterizing the Trans-Pecos region. A treatment of the Big Bend area has been produced by B. H. Warnock (1970), a professor of Botany at Sul Ross University and an authority on West Texas flora.

Little botanical work has been done specifically on the Fresno Creek area except for incidental collections and a preliminary survey by the Texas General Land Office in 1973.

Climatic conditions found here reflect those typically found in a desert environment. Water is limited with a mean annual precipitation of about 20-30 cm (8-12 in) and an evaporation rate of about 23 cm (90 in) a year which is the highest rate in the state. Mean annual temperatures are 8°-19°C (64°-66°F) and the warm season (number of days in which temperature is above freezing) extends from 230 to 245 days out of the year. The intensity of sunlight is indicated by a mean annual possible sunshine of 70-80% (Arbingast 1973).

These severe climatic conditions found in the Fresno Creek area, as in desert regions in general, produce a harsh environment for any form of life. In contrast to animals, the inability of plants to improve their situation by moving to a better area makes the survival of desert plants especially difficult. Consequently, the plants' survival and geographical distribution are dependent upon having characteristics that facilitate their ability to cope with demanding environmental conditions, primarily climate. The predominant plants of the desert are those that have successfully met the challenge of living in a water-scarce land. A well-known adaptation is the presence of water-storage tissue. Cacti are noted for their fleshy stems which store water and food. The agave and Spanish dagger store food and water in their leaf bases while sotol and bear grass use their roots and woody bases for storage. Herbaceous perennials, such as umbrella-wort (*Allionia choisya*), rain-lily (*Cooperia* sp.), and angel-trumpets (*Acleisanthes longiflora*), have tuberous roots or bulbs for storage and stems which arise only under favorable conditions. Ocotillo (*Fouquieria splendens*), which stores food reserves in its woody stems, drops its small leaves during dry periods in order to retard water loss by transpiration. The presence of very small leaves among desert plants is also thought to be a method of reducing possible water-loss by transpiration through the leaves; this pattern is exemplified by the acacias (*Mimosa biuncifera*), mesquite, white ratamy (*Krameria grayi*), and dalea (*Dalea formosa*). Creosote, tarbush, and resin-bush have resinous coatings on their leaves which may reduce the rate of water-loss. Similarly the presence of leaf hairs is considered to be a device to retard water-loss; this is seen in the silver leaf and species of *Croton*. Annual plants are able to remain in dormancy as a seed until the proper conditions of moisture and temperature exist to stimulate germination; this phenomenon is seen in bladderpod (*Lesquerella fendleri*), gilia (*Gilia rigidula*), nama (*Nama hispida*), and desert baileya. Ferns and selaginella possess the ability to roll up their fronds to reduce exposure to the heat.

In contrast to the harsh conditions of the dry mountain slopes and plains, the canyons enjoy more water and protection from the desiccating winds and intense sunlight. As a result, the relatively hospitable conditions in the canyons facilitate the growth of plants that have not undergone adaptations to severe desert conditions; these plants frequently are the same ones that are normally found in more favorable climates. It is assumed that they are relics from a time when the region had a wetter climate.

The information gathered in this study indicates that four major plant associations existed in the Fresno Creek study area, each corresponding to one of the major types of terrain; mountain slopes, alluvial gravel, riparian regions, and canyons. It was found that any one of these topographic areas tended to support a destinctive group of plants different in type and proportion from the others. That is not to say that within any one of the four areas there was a homogeneity of plants throughout. In fact, the combination of plants in two adjoining places frequently varied noticeably. This type of local variation in plant composition has suggested to some that each homogeneous local association of plants comprises a separate association. Our data suggested otherwise. Although local variations did occur, there was a persistent ubiquity of some species. The local variations that did occur within a single type of terrain were reasonably attributable to the random ebb and flow of plants over time. It is probable that each of the four major terrain types is capable of supporting many changing combinations of its favored plants. Since the data was consistent with this assumption, a conclusion of this report was that the major plant associations were dependent upon and generally contiguous with the four major types of terrain to be discussed below. It must be pointed out that plants characteristics of one of the four regions were not necessarily found there exclusively but they were notably more likely to there than elsewhere. The exception to this rule was a group of plants that was ubiquitous throughout the Fresno Creek study area. Among them were resin-bush, creosote, mesquite, bee-brush, and prickly-pear. Their presence constituted a point of overlap between the associations.

THE SLOPE ASSOCIATION

The general distribution of many species adapted to the desert is exemplified by the slope association. Dominant shrubs such as creosote, mesquite, resin bush, guayacan, and Engelmann prickly-pear (*Opuntia phaeacantha* var. *discata*) are found throughout the uplands of Fresno Creek.

Increased aridity, in addition to the impact of grazing, has probably played a role in determining the present plant composition. For instance, creosote, which characteristically grows on level terrain was well established on the slopes of the Fresno Creek area. A quadrat transect run on an igneous slope showed creosote to be the dominant shrub, accounting for ca. 14% of total coverage (Table 1). Leatherstem was frequent throughout and dominant in certain areas, a situation often indicative of overgrazing.

Transect data indicates variation in the amount of grass cover and considerable species diversity. Side oats grama (*Bouteloua curtipendula*), Wright three-awn (*Aristida wrightii*), purple three-awn (*Aristida purpurea*), and needlegrass (*Stipe eminens*) are the dominant grasses with wolftail (*Lycurus phleoides*), chino (*Boutelous ramosa*), arizona cottontop (*Trichachne californica*), fluffgrass (*Erioneuron pulchellum*), pappusgrass (*Pappophorum mucronulatum*), bristlegrass (*Setaria leucopila*), and mesa muhly (*Muhlenbergia monticola*) as minor components (Tables 1 and 3; Figs. 1 and 3).

A relatively inaccessible limestone slope proved to be one of the least-disturbed sites within this association. Shrubs were a very minor element (less than 2% of the total coverage) while grasses accounted for over half, 52.18% (Table 3). Important herbaceous species include rage sumpweed (*Iva ambrosiaefolia*), lechuguilla, candelilla, desert mentzelia (*Mentzelia multiflora*), and *Chamaesaracha villosa.* The paucity of shrubs, coupled with the prominence of grasses and herbs, represents perhaps the closest approach to a climax vegetation found within the slope association of this area.

The ephemeral spring annuals are often ignored in studies such as this. However, the tall, dried stems of the chisos bluebonnet (*Lupinus havardii*) were too obvious to overlook. On some slopes it was found to be the dominant herb. From accounts given by local residents of the area, the chisos bluebonnet formed a veritable carpet of blue over many of the slopes in the spring.

THE ALLUVIAL GRAVEL ASSOCIATION

The ubiquity of creosote is a characteristic feature of the alluvial gravel association in the Fresno Creek area. A quadrat transect in a typical creosote-dominant site showed it to account for over 60% of the total coverage (Table 2; Fig. 2). Other desert shrubs such as catclaw acacia, mesquite, quayacan, and ocotillo were infrequent. Fluffgrass, the dominant grass cover, was found in association with smaller populations of chino, wolf tail, and mesa muhly. The diversity among herbaceous species was low; hairy seed bahia and tasajillo (*Opuntia leptocaulis*) were the only significant representatives.

That aridity may be an important factor in the prominence of creosote is indicated by a line transect run in an alluvial gravel area found in the normal alluvial formation. Even though there was no significant difference in the total amount of ground cover, there was a more evenly diversified flora, including catclaw acacia, creosote, mesquite, and guayacan. Spiny hackberry and Spanish dagger (*Yucca torreyi*), lotebush, and resin bush comprised a minor association (Table 4; Fig. 4).

Notwithstanding the relative homogeneity of this association, a number of interesting plants were observed on the alluvial gravels. A single century plant (*Agave havardiana*) was in flower southwest of Arroyo Primero (see map). This is the only individual observed in this general vicinity, including the Solitario and Colorado Canyon. Schott acacia (*Acacia schottii*), distinguished by its linear leaflets and gland-dotted legumes, grows in a rather desolate extension of this association east of Fresno Creek and south of the Solitario (see map). In the same vicinity a sizable population, over 50 individuals, of false agave (*Hechtia scariosa*) was found. Elsewhere, false agave is represented by only a few individuals scattered on slopes or along canyon walls.

THE RIPARIAN ASSOCIATION

The riparian community encompasses a major drainage system and thus periodically receives sizable quantities of water, mostly in the late summer and fall months. With an ample underground water supply in the creekbed, Fresno Creek is capable of supporting large vegetation such as Arizona cottonwood, southwestern black willow, burro bush (*Hymenoclea monogyra*), seepwillow (*Baccharis glutinosa*), and desert willow (*Chilopsis linearis*). The scarcity of herbaceous cover indicates the frequency and force with which the creek flows.

The thin band of dense vegetation that lines the streambeds of the Solitario is not found at the edge of Fresno Creek. Often the stream forms an abrupt rather steep bank that leads directly into the creosote-dominated alluvial gravel association. In other places the streambed fans out, resulting in rather extensive flat alluvial areas covered with a dense growth of desert shrubs. Such areas constitute an overlap between the riparian and alluvial gravel associations.

In addition to Fresno Creek, there are numerous minor drainages that form tributaries of the various arroyos and canyons. A few individuals of desert willow and burro bush are scattered in the streambed. The banks support a relatively thick growth of catclaw acacia, mesquite, lotebush, spiny hackberry, and Wislizenus senna (*Cassia wislizenii*). These narrow green belts are in sharp contrast to the arid slopes and plains of the study area.

THE CANYON ASSOCIATION

Provided with a continual source of spring-fed water, Arroyo Primero and its tributary Chorro Canyon and Arroyo Segundo are distinguished by a luxuriant flora. The composition of the vegetation reflects the physical features of these canyons (Fig.5).

Arroyo Primero is an open canyon with relatively shallow, gradually sloping walls that admit more sunlight. The rush of intermittent rainwater through the canyon precludes the accumulation of much soil. Surface water is not continuous throughout Arroyo Primero. These factors result in a sporadic tree cover, the Arizona cottonwood and southwestern black willow tending to congregate around permanent water sources.

Numerous plants of the neighboring desert slopes, such as mescat acacia (*Acacia constricta*), catclaw mimosa (*Mimosa biuncifera*), resin bush, catclaw acacia, and guayacan, continue on into this canyon.

In contrast to Arroyo Primero, the sheer impenetrable walls of Arroyo Segundo provide protection from wind and sun. A closed canyon such as this allows for the accumulation of organic debris and material washed down from the slopes. These factors, in addition to abundant surface water, result in a continuous tree cover composed of ash (*Fraxinus velutina*), scrub oak (*Quercus pungens*), cottonwood, willow, Mexican buckeye (*Ungnadia speciosa*), and western soapberry (*Sapindus saponaria*). A comparable situation is found at the head of Chorro Canyon where the narrow canyon allows a dense tree cover similar to that found in Arroyo Segundo. An interesting population of oaks grows in the boxed canyon just above Madrid Falls. In close proximity are found both *Quercus oblongifolia* and *Quercus pungens*, along with intergrading forms.

Aside from these distinguishing characteristics, the canyons share many common elements, the most spectacular of which are the falls of Chorro Canyon and Arroyo Segundo. The underlying walls are carpeted with maidenhair fern, epipactis, wild rye, and columbines with delicate waxy yellow flowers. Canyon grape (*Vitis arizonica*) and poison ivy (*Rhus toxicodendron*) abound. The moist crevices are inhabited by monkeyflower and brook weed.

The water falls serve to replenish a series of pools throughout these canyons. Here a diversity of grasses thrives including bentgrass (*Agrostis semiverticillata*), dropseed (*Sporobolus contractus*), bristle grass (*Setaria leucopila*), bluestem (*Andropogon glomeratus*), knot root bristle grass (*Setaria geniculata*), and silver bluestem (*Bothriochloa saccharoides*). In the shallow pools *Cyperus laevigatus*, spikesedge (*Eleocharis macrostachya*), horsetail, cattail, and rush (*Juncus nodosa*), normally found in wet areas of the state, are locally abundant, along with such water-loving species as seedbox (*Ludwigia palustris*), wild petunia, water hyssop, *Lythrum californicum*, *Centaurium beyrichii*, and rosilla (*Helenium quadridentatum*). One of the more showy herbs characteristic of the canyon areas is the cardinal flower (*Lobelia cardinalis*). This erect perennial with its deep-red tubular flowers is commonly visited by hummingbirds.

Although an area of high productivity, these canyons are susceptible to disturbing influences. The presence of cattle in Chorro Canyon has noticeably damaged the vegetation, especially the tender herbaceous species. In many instances, the horsetail and several grasses have been grazed to the ground. The moist canyons nurture such a specialized and vulnerable assemblage of plants that special care and planning are required in order to preserve the delicate balance now in existence.

RARE PLANTS

The *Aquilegia* found in the canyons of the Fresno Creek drainage is one of a number of rare Trans-Pecos columbines. Each recognized species appears to be endemic to a particular mountain range. *Aquilegia chrysantha* is found in the Davis Mountains, *A. longissima* in the Chisos Mountains, *A. hinckleyana* in the Sierra Vieja Mountains, and *A. chaplinei* in the Guadelupe Mountains.

The populations of *Aquilegia* from Madrid Falls and Arroyo Segundo exhibit close affinities to two of the Trans-Pecos taxa. Floral characteristics such as spur length (3.5 cm), sepal length (1.5 cm), and petal length (ca. 10mm) approach those of *A. chaplinei.* However, the triternate leaves, which average about 5 cm in length, are more typical of *A. longissima.* Therefore, the columbine inhabiting the canyons of the Fresno Creek drainage has tentatively been identified as *A. chaplinei* (aff. *A. longissima*).

Aquilegia is a poorly understood genus taxonomically. Many of the named species appear to be geographical races (Grant 1971). The presence of some common characteristics among otherwise distinct species certainly suggests that the isolated moist, cool islands that support each columbine colony may be, or may have been, connected by unknown factors. The answer to this question must wait for future research.

Gray's cloakfern (*Notholaena grayi*) was collected from the Box Canyon above Madrid Falls. Typically found on talus slopes or in rock crevices, this fern is considered rare in the Trans-Pecos region and on the Edwards Plateau.

Sisymbrium purpusii, a spring annual in the mustard family, is known within the United States only from the Smith Ranch in Fresno Canyon. This rare species also extends into Mexico.

The mouth of Fresno Creek supports a very rare endemic mustard, *Thelypodium tenue.* Fresno is the only known locality for this early spring annual.

SUMMARY AND COMPARISON OF SOLITARIO, FRESNO CREEK, AND COLORADO CANYON

The Solitario, as the name implies, remains distinct from the Fresno Creek and Colorado Canyon areas in a number of features. Heath cliffrose (*Cowania ericaefolia*), toothed service-berry, Gregg ash, Arizona oak (*Quercus arizonica*), Gray oak (*Quercus grisea*), redberry juniper (*Juniperus pinchotii*), and rough mortonia were collected only from the Solitario. Their restriction may be a result of the structure of this geological formation itself since it forms a partial barrier to seed dispersal. Environmental factors such as temperature, edaphic properties, water supply, or altitude may also prohibit the establishment of these plants in the other areas.

Another distinquishing feature of the Solitario is the lack of a permanent water supply. All the drainages are dependent upon ample rainfall in order to run, in contrast to Fresno Creek with its water falls and springs and to Colorado Canyon with the Rio Grande and numerous springs along the northward-running canyons. As a result of a permanent water source, Fresno Creek and Colorado Canyon contain fecund "oases" that nurture growths of sedges, rushes, ferns, and numerous grasses, along with ash (*Fraxinus velutina*) and cottonwood (*Populus arizonica*).

The slope community is for the most part continuous throughout. Distribution of sotol appears to follow an altitudinal gradient, for it is a characteristic element in the Solitario and higher slopes along Fresno Creek but is conspicuously absent from the slopes of the Colorado Canyon area. Increased aridity and grazing pressures in these latter two areas may be responsible for the relative abundance of lechuguilla and leatherstem as compared to the slopes of the Solitario.

The alluvial gravel association is fairly consistent except that creosote is far more extensive in the Fresno Creek and Colorado Canyon areas than in the Solitario. Once again an altitudinal phenomenon may be involved, resulting in higher temperatures and increased water-loss at the lower elevations. Man may have had a stronger impact on the vegetation of Fresno Creek and Colorado Canyon, resulting in further deterioration of grasslands, followed by the invasion of desert shrubs such as creosote. The isolation of the Solitario is also reflected by the scarcity of introduced species. This situation is in sharp contrast to Colorado Canyon area where introductions such as salt cedar (*Tamarix gallica*), tree tobacco (*Nicotiana glauca*), and giant reed (*Arundo donax*) predominate along the Rio Grande.

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APPENDIX 1

Localities for quadrat transects presented in Table I-III.

Table 1—East facing slope of NE corner of Rincon Mountain (Solitario 15-minute quadrangle map).
Table 2—East facing slope of peak marked No. 3989, E of Rincon Mountain (Solitario 15-minute quadrangle map).
Table 3—Alluvial gravel flat, East of Fresno Creek and across from Arroyo Segundo (Solitario 15-minute quadrangle map).

Locality for line transect presented in Table IV.

Table 4—Alluvial plain between foot of Rincon Mountain and Fresno Creek (Solitario 15-minute quadrangle map).

APPENDIX 2

Explanation of symbols used in tables.

Q = Total quadrats in which species occured.

RFi = Raw Frequency = Present quadrats in which species occurred

$$\text{RFii} = \text{Relative Frequency} = \frac{\text{Q of species}}{\text{Total Q}}$$

$$\text{RDi} = \text{Relative Density} = \frac{\text{Total individuals of species}}{\text{Total individuals of all species}}$$

TI = Total Individuals

$$\text{RC} = \text{Raw Cover} = \frac{\text{Total area covered by species}}{\text{Total area sampled}}$$

$$\text{RDii} = \text{Relative Dominance} = \frac{\text{Area covered by species}}{\text{Area covered by all species}}$$

TA = Index of the total area covered by species.

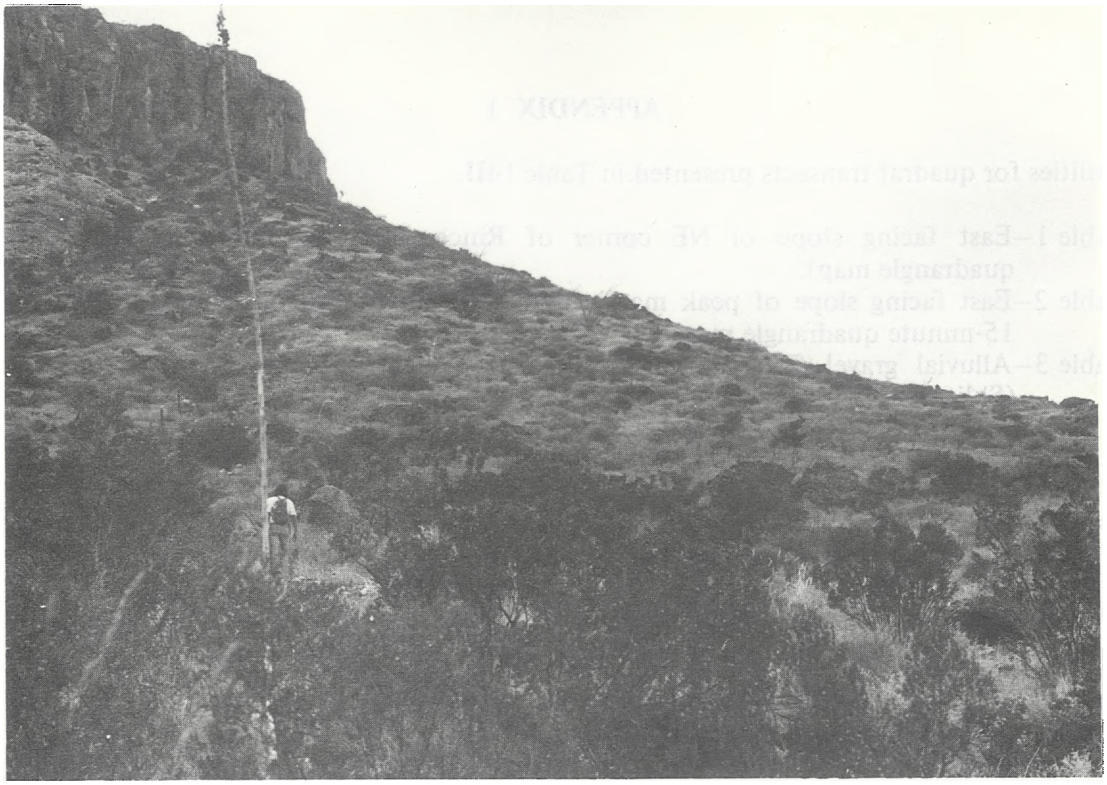

FIGURE 1

The Slope Association – site for Quadrat Transect 9.

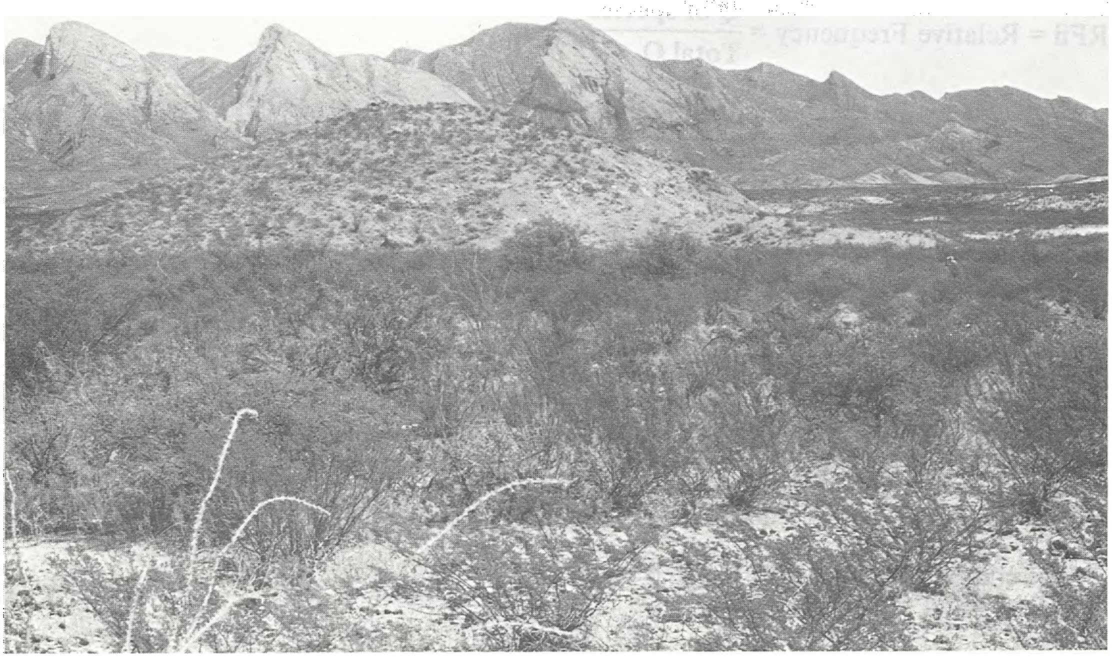

FIGURE 2

The Alluvial Gravel Association – site for Quadrat Transect 10.
Solitario Uplift in Background.

TABLE I
Quadrat Transect 9

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida wrightii	14	28	9.72	7.94	27	1.98	4.98	99
Bouteloua curtipendula	11	22	7.64	5.29	18	3.26	8.20	163
Erioneuron pulchellum	3	6	2.08	4.12	14	.5	1.26	25
Lycurus phleoides	10	20	6.94	7.06	24	1.34	3.37	67
Muhlenbergia monticola	1	2	0.69	0.29	1	.06	0.15	3
Pappophorum mucronatum	1	2	0.69	0.29	1	.06	0.15	3
Setaria leucopila	1	2	0.69	0.29	1	.2	0.50	10
Stipa eminens	2	4	1.39	0.59	2	.6	1.51	30
HERBS								
Agave lecheguilla	4	8	2.78	1.18	4	1.5	3.77	75
Allionia choisya	5	10	3.47	2.65	9	.62	1.56	31
Bahia absinthifolia	33	66	22.92	37.94	129	4.24	10.66	212
Bahia pedata	1	2	0.69	0.29	1	.2	0.50	10
Chamaesaracha villosa	2	4	1.39	0.59	2	.26	0.65	13
Dyssodia pentachaeta	7	14	4.86	7.65	26	2.36	5.94	118
Euphorbia antisyphilitica	1	2	0.69	0.29	1	.9	2.26	45
Iva ambrosiaefolia	15	30	10.42	10.59	36	3.98	10.01	199
Jatropha dioica	7	14	4.86	2.65	9	2.1	5.28	105
Lupinus havardii	10	20	6.94	5.29	18	3.3	8.30	165
Machaeranthera scabrella	1	2	0.69	0.29	1	.02	0.05	1
Opuntia engelmannii	3	6	2.08	0.88	3	1.3	3.27	65
Opuntia leptocaulis	4	8	2.78	1.47	5	1.02	2.57	51
Perityle parryi	1	2	0.69	0.29	1	.06	0.15	3
Zexmenia brevifolia	1	2	0.69	0.29	1	.4	1.01	20
TREES & SHRUBS								
Larrea tridentata	3	6	2.08	0.88	3	5.6	14.08	280
Porlieria ongustifolia	1	2	0.69	0.29	1	.4	1.00	20
Prosopis glandulosa	2	4	1.39	0.59	2	3.5	8.80	175
TOTAL	144		99.95%	99.97%	340	39.76%	99.98%	1988%

TABLE II
Quadrat Transect 10

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Bouteloua ramosa	9	22.5	6.87	3.16	18	0.80	1.44	32
Erioneuron pulchellum	34	85.0	25.95	41.58	237	4.57	8.25	183
Lycurus phleoides	3	7.5	2.29	0.70	4	0.10	0.18	4
Muhlenbergia monticola	1	2.5	.76	0.18	1	0.02	0.04	1
HERBS								
Bahia absinthifolia	36	90.0	27.48	42.63	243	5.77	10.41	231
Dyssodia pentachaeta	4	10.0	3.05	0.70	4	0.20	0.36	8
Echinocereus stramineus	1	2.5	.76	0.18	1	0.02	0.04	1
Iva ambrosiaefolia	6	15.0	4.58	2.63	15	1.47	2.66	59
Jatropha dioica	1	2.5	.76	0.18	1	2.50	4.50	100
Nama hispida	5	12.5	3.82	1.58	9	0.80	1.44	32
Opuntia leptocaulis	4	10.0	3.05	0.70	4	2.80	5.05	112
TREES & SHRUBS								
Fouquieria splendens	2	5.0	1.53	0.35	2	3.00	5.41	120
Larrea tridentata	25	62.5	19.08	5.44	31	33.37	60.19	1335
TOTAL	131		99.98%	100%	570	55.42%	99.97%	2218%

FIGURE 3
The Slope Association – site for Quadrat Transect 11.

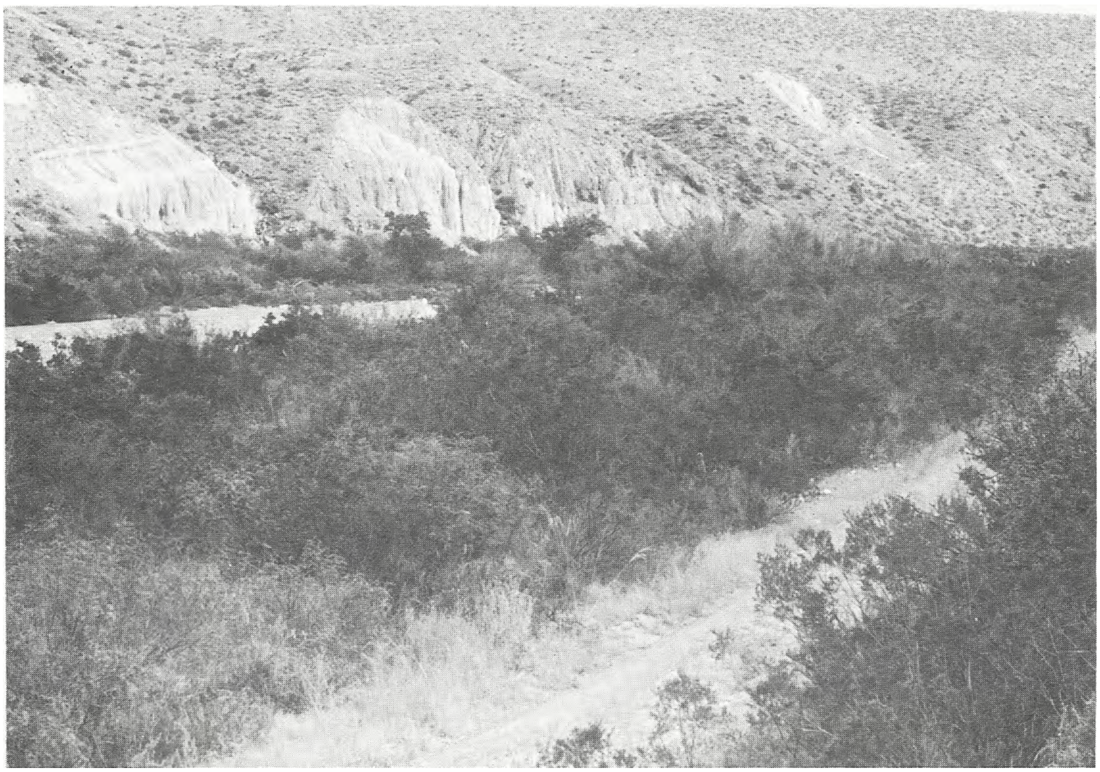

FIGURE 4
The Alluvial Gravel Association – site for Line Transect 2.

TABLE III
Quadrat Transect 11

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida purpurea	15	37.5	12.09	11.64	22	2.30	6.37	92
Aristida wrightii	5	12.5	4.03	4.76	9	2.30	6.37	92
Bouteloua curtipendula	17	42.5	13.71	15.34	29	6.65	18.41	266
Bouteloua ramosa	5	12.5	4.03	3.17	6	1.87	5.19	75
Erioneuron pulchellum	2	5.0	1.61	1.06	2	0.42	1.18	17
Stipa neomexicana	14	35.0	11.29	11.11	21	4.32	11.97	173
Trichachne californica	4	10.0	3.23	2.12	4	0.95	2.63	38
HERBS								
Agave Lecheguilla	7	17.5	5.64	3.70	7	2.50	6.92	100
Chamaesaracha villosa	7	17.5	5.64	4.23	8	1.45	4.01	58
Cyphomeris gypsophiloides	1	2.5	0.81	1.06	2	0.12	0.35	5
Dasylirion texanum	2	5.0	1.61	1.06	2	0.75	2.08	30
Echinocereus triglochidiatus	1	2.5	0.81	0.53	1	0.50	1.38	20
Ephedra aspera	2	5.0	1.61	1.06	2	0.55	1.52	22
Euphorbia antisyphilitica	2	5.0	1.61	3.17	6	1.95	5.40	78
Evax verna	1	2.5	0.81	0.53	1	0.12	0.35	5
Hedeoma drummondii	6	15.0	4.84	3.17	6	0.60	1.66	24
Iva ambrosiaefolia	12	30.0	9.68	10.05	19	2.32	6.44	93
Mentzelia multiflora	4	10.0	3.23	2.12	4	2.12	5.88	85
Opuntia engelmannii	4	10.0	3.23	2.65	5	2.57	7.13	103
Perityle parryi	2	5.0	1.61	3.70	7	0.50	1.38	20
Polygala longa	1	2.5	0.81	0.53	1	0.02	0.07	1
Ruellia parryi	2	5.0	1.61	1.06	2	0.57	1.59	23
TREES & SHRUBS								
Bernardia obovata	1	2.5	0.81	0.53	1	0.07	0.21	3
Gymnosperma glutinosum	5	12.5	4.03	2.65	5	0.22	0.62	9
Viguiera stenoloba	2	5.0	1.61	8.99	17	0.32	0.90	13
TOTAL	**124**		**99.99%**	**99.99%**	**189**	**36.06%**	**100.01%**	**1445%**

TABLE IV
Line Transect 2

	TI	RDi	Coverage in Meters	RC	RDii
HERBS					
Baileya multiradiata	2	3.45	0.20	0.20	.08
Iva ambrosiaefolia	4	6.90	1.35	1.35	2.86
TREES & SHRUBS					
Acacia greggii	9	15.52	10.85	10.85	22.99
Celtis pallida	1	1.72	2.25	2.25	5.06
Larrea tridentata	24	41.38	10.80	10.80	22.88
Porlieria angustifolia	3	5.17	3.50	3.50	7.42
Prosopis glandulosa	10	17.24	14.45	14.45	30.61
Viguiera stenoloba	1	1.72	0.50	0.50	1.06
Yucca torreyi	1	1.72	2.50	2.50	5.3
Ziziphus obtusifolia	3	5.17	0.80	0.80	1.69
TOTAL	**58**	**99.99%**	**47.20**	**47.2%**	**99.95%**

FIGURE 5

The Canyon Association – as represented in Arroyo Segundo.
Fresno Peak in background.

FRESNO CREEK SPECIES LIST

A – ANNUAL
P – PERENNIAL
I – INTRODUCED
N – NATIVE
* – ENDEMIC TO (OR RARE IN) TEXAS

SCIENTIFIC NAME		COMMON NAME
SELAGINELLACEAE		SPIKEMOSS FAMILY
Selaginella lepidophylla (Hook. & Grev.) Spring	NP	Resurrection Plant, Siempre Viva
Selaginella peruviana (Milde.) Hieron.	NP	
EQUISETACEAE		HORSETAIL FAMILY
Equisetum laevigatum L.	NP	Cola de Caballo
POLYPODIACEAE		TRUE FERN FAMILY
Adiantum capills-veneris L.	NP	Maidenhair Fern, Culantrillo
Notholaena aurae (Poir.) Desv.	NP	Slender Cloakfern
**Notholaena grayi* Davemp.	NP	Gray's Cloakfern
Notholaena sinuata (Lag.) var. *sinuata*	NP	Bulb Cloakfern
Notholaena sinuata (Lag.) var. *integerrima* Hook.	NP	
Notholaena sinuata (Lag.) var. *cochisensis* (Goodd.) Weath.	NP	Jimmyfern, Helechillo
EPHEDRACEAE		EPEDRA FAMILY
Ephedra antisyphilitica C.A. Mey	NP	Clapweed, Popote
Ephedra aspera Engelm.	NP	Boundary Ephedra, Popotilla
Ephedra trifurca Torr.	NP	Longleaf Ephedra, Canatilla
TYPHACEAE		CAT-TAIL FAMILY
Typha latifolia L.	NP	Common Cat-tail, Tule Espadilla
POACEAE		GRASS FAMILY
Agrostis semiverticillata (Forsk.) Christ	NP	Water Bentgrass
Andropogon glomeratus (Walt.) B.S.P.	NP	Bushy Beardgrass
Aristida ternipes Cav.	NP	Spider Grass
Aristida wrightii Nash	NP	Wright Three-Awn
Bothriochloa saccharoides (Sw.) Rydb.	NP	Silver Beardgrass
Bouteloua curtipendula (Michx.) Torr.	NP	Side-Oats Grama
Bouteloua ramosa Vasey	NP	Chino Grama, Chinograss
Cynodon dactylon (L.) Pers.	NP	Bermuda Grass, Pata de Gallo
Elymus virginicus L.	NP	Virginia Whiterye
Eragrostis neomexicana Vasey	NA	New Mexico Lovegrass
Erioneuron pulchellum (H.B.K.) Tateoka	NP	Fluffgrass
Lycurus phleoides H.B.K.	NP	Wolftail
Muhlenbergia monticola Buckl.	NP	Mesa Muhly
Setaria geniculata (Lam.) Beauv.	NP	Knotroot Bristlegrass
Setaria leucopila (Scribn. & Merr.) K. Schum.	NP	
Sporobolus airoides (Torr.) Torr.	NP	Alkali Sacaton
Sporobolus contractus Hitchc.	NP	Spike Dropseed
Stipa eminens Cav.	NP	Southwestern Needlegrass
Trichachne californica (Benth.) Chase	NP	Arizona Cottontop
CYPERACEAE		SEDGE FAMILY
Cladium jamaicense Crantz	NP	Saw-Grass
Cyperus laevigatus L.	NP	Smooth Flatsedge

SCIENTIFIC NAME		COMMON NAME
Eleocharis macrostachya Britton	NP	Large Spikesedge
Eleocharis montevidensis Kunth	NP	Sand Spikesedge
Fuirena simplex Vahl.	NP	Western Umbrellasedge
BROMELIACEAE		PINE-APPLE FAMILY
Hechtia scariosa Smith	NP	Rough False-Agave
COMMELINACEAE		SPIDERWORT FAMILY
Commelina erecta L. var. *angustifolia* (Michx.) Fern	NP	Hierba del Pollo
JUNCACEAE		RUSH FAMILY
Juncus nodosa L.	NP	Jointed Rush
Juncus torreyi Cov.	NP	Torrey Rush
LILIACEAE		LILY FAMILY
Dasylirion leiophyllum Engelm.	NP	Smooth Sotol
Dasylirion texanum Scheele	NP	Texas Sotol
Nolina erumpens (Torr.) Wats.	NP	Bear Grass
Yucca thompsoniana Trel.	NP	Thompson Yucca
Yucca torreyi Shafer	NP	Torrey Yucca
AMARYLLIDACEAE		AMARYLLIS FAMILY
Agave havardiana Trel.	NP	Harvard Agave
Agave lecheguilla Torr.	NP	Lechuguilla
ORCHIDACEAE		ORCHID FAMILY
Epipactis gigantea Dougl.	NP	Stream Epipactis
SALICACEAE		WILLOW FAMILY
Populus arizonica Sarg.	NP	Arizona Cottonwood, Chopo
Salix gooddingii Ball var. *variabilis* Ball	NP	Southern Black Willow
JUGLANDACEAE		WALNUT FAMILY
Juglans microcarpa Berl.	NP	Little Walnut
FAGACEAE		BEECH FAMILY
Quercus oblongifolia Coult.	NP	
Quercus pungens Liebm.	NP	Scrub Oak
ULMACEAE		ELM FAMILY
Celtis pallida Torr.	NP	Desert Hackberry, Granjeno
Celtis reticulata Torr.	NP	Palo Blanco, Netleaf Hackberry
URTICACEAE		NETTLE FAMILY
Parietaria obtusa Rydb.	NA	
VISCACEAE		MISTLETOE FAMILY
Phoradendron tomentosum (DC.) Gray	NP	Injerto
ARISTOCHIACEAE		BIRTHWORT FAMILY
Aristolochia wrightii Seem.	NP	Wright Dutchman's-Pipe
POLYGONACEAE		KNOTWEED FAMILY
Eriogonum jamesii Benth.	NA	James Wildbuckweed

SCIENTIFIC NAME		COMMON NAME
Eriogonum rotundifolium Benth.	NA	Roundleaf Wildbuckweed
Persicaria hydropiperoides (Michx.) Small	NA	
CHENOPODIACEAE		GOOSEFOOT FAMILY
Atriplex acanthocarpa (Torr.) Wats.	NP	Armed Saltbush
Atriplex canescens (Pursh) Nutt.	NP	Four-Wing Saltbush
Atriplex obovata Moq.	NP	Silver Saltbush
Chenopodium berlandieri Moq.	IA	Pitseed Goosefoot
AMARANTHACEAE		AMARANTH FAMILY
Amaranthus blitoides Wats.	NA	Prostrate Pigweed, Quelite Manchado
Froelichia arizonica Thornb.	NP	Arizona Snakecotton
Tidestromia lanuginosa (Nutt.) Standl. var. *lanuginosa*	NA	Espanta Vaqueros
NYCTAGINACEAE		FOUR-O'CLOCK FAMILY
Acleisanthes longiflora Gray	NP	Angel Trumpets
Allionia choisya Standl.	NA	Smooth Umbrella-Wort
Allionia incarnata L.	NP	Pink Windmills, Hierba de la Hormiga
Boerhaavia coccinea Mill.	NP	Scarlet Spiderling
Boerhaavia intermedia E.M. Jones	NA	Spreading Spiderling
Cyphomeris gypsophiloides (Mart. & Gal.) Standl.	NP	Red Cyphomeris
Selinocarpus angustifolius Torr.	NP	Narrowleaf Moonpod
PHYTOLACCACEAE		POKEWEED FAMILY
Rivina humilis L.	NP	Pigeon-Berry, Coralito
PORTULACACEAE		PURSLANE FAMILY
Portulaca mundula I.M. Johnst.	NA	Shaggy Portulaca, Chisme
Portulaca oleracea L.	NA	Purslane, Verdolaga
CERATOPHYLLACEAE		HORNWORT FAMILY
Ceratophyllum demersum L.	NP	Common Hornwort
RANUNCULACEAE		CROWFOOT FAMILY
**Aquilegia chaplinei* Standl. (aff. *A longissima* Gray)	NP	Chapline Columbine
Clematis alpina Mill.	NP	Alpine Clematis
Clematis drummondii T. & G.	NP	Texas Virgin's Bower
BERBERIDACEAE		BARBERRY FAMILY
Berberis trifoliolata Moric.	NP	Agarito, Currant-of-Texas
PAPAVERACEAE		POPPY FAMILY
Argemone chisosensis G.B. Ownbey	NA	Chisos Pricklepoppy
CRUCIFERAE		MUSTARD FAMILY
Lepidium virginicum L. var. *medium* (Greene) H.L. Hitchc.	NA	Virginia Pepperweed, Lentejilla
Lesquerella purpurea (Gray) Wats.	NP	Rose Bladderpod
Nerisyrenia camporum (Gray) Greene	NP	Mesa Greggia
Rorippa nasturtium-aquaticum (L.) Hayek	IP	Water-Cress
Selenia dissecta Torr.	NA	Texas Selenia
**Sisymbrium purpusii* (Brandeg.) Schulz	NA	
**Thelypodium tenue* Roll.	NA	
CAPPARIDACEAE		CAPER FAMILY
Polanisia dodecandra (L.) DC. var. *trachysperma* (T. & G.) Iltis.	NA	Roughseed Clammyweed

SCIENTIFIC NAME		COMMON NAME
ROSACEAE		ROSE FAMILY
Prunus havardii Wright	NP	Havard Plum
LEGUMINOSAE		LEGUME FAMILY
Acacia constricta Gray	NP	Mescat Acacia
Acacia greggii Benth.	NP	Catclaw
Acacia neovernicosa Isley		
Acacia schottii Torr.	NP	Schott Acacia
Cassia bauhinioides Gray	NP	Two-Leaved Senna
Cassia lindheimeriana Scheele	NP	Lindheimer Senna
Cassia wislizenii Gray	NP	Wislizenus Senna
Dalea neomexicana (Gray) Cory	NP	New Mexico Dalea
Lupinus havardii Wats.	NA	Chisos Bluebonnet
Melilotus indicus (L.) All.	IA	Annual Yellow Sweetclover
Mimosa biuncifera Benth.	NP	Cat's-Claw Mimosa
Phaseolus wrightii Gray	NP	Wright Bean
Prosopis glandulosa Torr. var. *torreyana* (L. Benson) M.C. Johnst.	NP	Western Honey Mesquite
Rhynchosia texana T. & G.	NP	Texas Stoutbean
Sophora secundiflora (Ort.) DC.	NP	Texas Mountain Laurel, Frijolillo
KRAMERIACEAE		RATANY FAMILY
Krameria grayi Rose & Painter	NP	White Ratany
LINACEAE		FLAX FAMILY
Linum rigidum Pursh var. *berlandieri* (Hook.) T. & G.	NA	Berlandier Flax
ZYGOPHYLLACEAE		CALTROP FAMILY
Larrea tridentata (DC.) Cov.	NP	Creosote Bush, Gobernadora
Porlieria angustifolia (Engelm.) Gray	NP	Guayacan, Soap-Bush
MALPIGHIACEAE		MALPIGHIA FAMILY
Janusia gracilis Gray	NP	Slender Janusia
POLYGALACEAE		MILKWORT FAMILY
Polygala longa Blake	NP	Rock Milkwort
EUPHORBIACEAE		SPURGE FAMILY
Argythamnia neomexicana Muell.	NP	New Mexico Wildmercury
Bernardia obovata I.M. Johnst.	NP	Desert Myrtlecroton
Croton dioicus Cav.	NP	Rosval, Hierba del Gato
Croton pottsii (Kl.) Muell. Arg.	NP	Leather-Weed
Croton sancti-lazari Croizat	NP	
Croton torreyanus Muell. Arg.	NP	Vara Blanca
Euphorbia antisyphilitica Zucc.	NP	Candelilla
Jatropha dioica Cerv. var. *graminea* McVaugh.	NP	Sangre de Drago, Leather Stem
Tragia ramosa Torr.	NP	Catnip Noseburn
ANACARDIACEAE		SUMAC FAMILY
Rhus microphylla Engelm.	NP	Littleleaf Sumac
Rhus toxicodendron L.	NP	Poison Ivy, Hiedra
Rhus virens Gray	NP	Evergreen Sumac, Lentisco
SAPINDACEAE		SOAP-BERRY FAMILY
Sapindus saponaria L. var. *drummondii* (H. & A.) L. Benson	NP	Western Soapberry, Jaboncillo
Ungnadia speciosa Endl.	NP	Mexican Buckeye, Monilla

SCIENTIFIC NAME		COMMON NAME
RHAMNACEAE		BUCKTHORN FAMILY
Ziziphus obtusifolia (T. & G.) Gray	NP	Lotebush, Clepe
VITACEAE		GRAPE FAMILY
Cissus incisa (Nutt.) Des Moul.	NP	Hierba del Buey, Treebine
Vitis arizonica Engelm. var. *arizonica*	NP	Canyon Grape
Vitis arizonica Engelm. var. *glabra* Munson	NP	Canyon Grape
MALVACEAE		MALLOW FAMILY
Abutilon incanum (Link) Sweet	NP	Indian Mallow, Tronadora
Abutilon malacum Wats.	NP	
Abutilon wrightii Gray	NP	Wright's Abutilon
Herissantia crispa (L.) Brizicky	NA	Netvein Mallow, Colotahue
Hibiscus coulteri Harv.	NP	Desert Rose-Mallow
Hibiscus denudatus Benth.	NP	Pale-Face Rose-Mallow
Sida hederacea (Hook.) Gray	NP	Dollar Weed, Alkali Mallow
Sphaeralcea angustifolia (Cav.) D. Don	NP	Narrowleaf Globemallow
TAMARICACEAE		TAMARISK FAMILY
Tamarix aphylla (L.) Karst.	IP	
FOUQUIERIACEAE		OCOTILLO FAMILY
Fouquieria splendens Engelm.	NP	Ocotillo
KOEBERLINIACEAE		ALLTHORN FAMILY
Koeberlinia spinosa Zucc.	NP	Junco, Allthorn
LOASACEAE		STICKLEAF FAMILY
Cevallia sinuata Lag.	NP	Stinging Cevallia
Eucnide bartonioides Zucc.	NA	Yellow Rocknettle
Mentzelia multiflora (Nutt.) Gray	NA	Desert Mentzelia
Mentzelia oligosperma Sims	NP	Chicken Thief, Stickleaf
CACTACEAE		CACTUS FAMILY
Ariocarpus fissuratus (Engelm.) K. Schum.	NP	Living Rock
Echinocactus horizonthalonius Lem.	NP	Turk's Head, Manca Caballo
Echinocactus uncinatus Gal.	NP	Fishhook Cactus
Echinocactus texensis Hopffer	NP	Horse Crippler, Devil's Pincushion
Echinocereus enneacanthus Engelm. var. *stramineus* (Engelm.) L. Benson	NP	Strawberry Cactus
Echinocereus pectinatus (Scheidw.) Engelm. var. *neomexicanus* (Coult.) L. Benson	NP	Rainbow Cactus
Echinocereus triglochidatus Engelm.	NP	Claret-Cup
Epithelantha micromeris (Engelm.) Weber	NP	Button Cactus
Mammillaria pottsii Scheer	NP	Potts Mammillaria
Opuntia imbricata (Haw.) DC.	NP	Tree Cholla, Coyonostle
Opuntia leptoculis DC.	NP	Christman Cactus, Tasajillo
Opuntia phaeacantha Engelm. var. *discata* (Engelm.) L. Benson and Walkington	NP	Engelmann Prickly-Pear
Opuntia rufida Engelm.	NP	Blind Prickly-Pear
Opuntia violacea Engelm. var. *macrocentra* (Engelm.) L. Benson	NP	Purple Prickly-Pear
LYTHRACEAE		LOOSESTRIFE FAMILY
Lythrum californicum T. & G.	NP	Hierba del Cancer

SCIENTIFIC NAME		COMMON NAME
ONAGRACEAE		EVENING PRIMROSE FAMILY
Gaura coccinea Pursh	NP	Scarlet Gaura
Ludwigia repens Forst.	NP	Roundlead Seedbox
Oenothera rosea Ait.	NP	Rose Sundrops
PRIMULACEAE		PRIMROSE FAMILY
Samolus cuneatus Small	NP	Limerock Broodweed
EBENACEAE		EBONY FAMILY
Diospyros texana Scheele	NP	Mexican Persimmon
OLEACEAE		OLIVE FAMILY
Forestiera angustifolia Torr.	NP	Desert Olive, Panalero
Fraxinus velutina Torr.	NP	Mexican Ash, Fresno
Menodora longiflora Gray	NP	Showy Menodora, Twin-Pod
LOGANIACEAE		LOGANIA FAMILY
Buddleja marrubiifolia Benth.	NP	Woolly Butterflybush
GENTIANACEAE		GENTIAN FAMILY
Centaurium beyrichii (T. & G.) C.L. Robinson var. *beyrichii*	NA	Mountain Pink
CONVOVULACEAE		MORNING GLORY FAMILY
Convolvulus equitans Benth.	NA	
POLEMONIACEAE		PHLOX FAMILY
Gilia stewartii I.M. Johnst.	NA	
HYDROPHYLLACEAE		WATERLEAF FAMILY
Nama havardii Gray	NA	Havard Nama
Nama hispidum Gray	NA	Rough Nama
Phacelia congesta Hook.	NA	Spike Phacelia
Phacelia robusta (Macbr.) I.M. Johnst.	NA	Stout Phacelia
BORAGINACEAE		BORAGE FAMILY
Cryptantha mexicana (Brandegee) I.M. Johnst.	NA	Mexican Cryptantha
VERBENACEAE		VERVAIN FAMILY
Aloysia gratissima (Gill. & Hook.) Troncoso	NP	Common Bee-Brush, Palo Amarillo
Aloysia wrightii (Gray) Heller	NP	Oreganillo
Phyla incisa Small	NP	Frogfruit
Phyla strigulosa (Mart. & Gal.) Moldenke	NP	Diamond-Leaf Frogfruit
Verbena neomexicana (Gray) Small var. *hirtella* Perry	NP	Hillside Vervain
LABIATAE		MINT FAMILY
Hedeoma drummondii Benth. var. *drummondii*	NP	Drummond Hedeoma
Marrubium vulgare L.	IP	Common Horehound, Marrubio
Salvia regla Cav.	NP	Mountain Sage
Scutellaria drummondii Benth.	NA	Drummond Skullcap
SOLANACEAE		POTATO FAMILY
Chamaesaracha villosa Rydb.	NP	
Datura wrightii Regel	NA	Indian Apple, Sacred Datura
Nicotiana glauca Grah.	IP	Tree Tobacco, Rape

SCIENTIFIC NAME		COMMON NAME
Nicotiana trigonophylla Dunal	NA	Desert Tobacco, Tabaquillo
Petunia parviflora Juss.	IA	Wild Petunia, Seaside Petunia
Physalis subulata Rydb. var. *neomexicana* (Rydb.) Waterfall	NA	
Solanum eleagnifolium Cav.	NP	Silverleaf Nightshade, Trompillo
SCROPHULARIACEAE		FIGWORT FAMILY
Bacopa monnieri (L.) Wettst.	NP	Coastal Waterhyssop
Leucophyllum frutescens (Berl.) I.M. Johnst.	NP	Cenizo, Purple Sage
Maurandya antirrhinifolia Humb. & Bonpl.	NP	Snapdragon Vine
Mimulus glabratus H.B.K.	NP	Monkeyflower
Penstemon baccharifolius Hook.	NP	Charisleaf Penstemon
Penstemon havardii Gray	NP	Havard Penstemon
BIGNONIACEAE		CATALPA FAMILY
Chilopsis linearis (Cav.) Sweet.	NP	Desert Willow, Mimbre
Tecoma stans (L.) Juss. var. *angustata* Rehd.	NP	Trumpet-Flower, Esperanza
MARTYNIACEAE		UNICORN-PLANT FAMILY
Proboscidea sp.		
ACANTHACEAE		ACANTHUS FAMILY
Carlowrightii arizonica Gray	NP	
Ruellia parryi Gray	NP	Parry Ruellia
RUBIACEAE		MADDER FAMILY
Cephalanthus occidentalis L.	NP	Common Buttonbush, Honey-Balls
Galium microphyllum Gray	NP	Bracted Bedstraw
Hedyotis acerosa Gray	NP	Needleleaf Bluets
Hedyotis nigricans (Lam.) Fosb. var. *rigidiuscola* (Gray) Shinners	NP	Stiff Bluets
CAMPANULACEAE		BLUEBELL FAMILY
Lobelia cardinalis L. var. *pseudosplendens* McVaughn	NP	Cardinal-Flower
COMPOSITAE		SUNFLOWER FAMILY
Artemisia ludoviciana Nutt.	NP	Western Mugwort
Aster spinosus Benth.	NP	Mexican Devilweed
Baccharis glutinosa (R. & P.) Pers.	NP	Jara, seepwillow
Bahia absinthifolia Benth.	NP	Hairyseed Bahia
Bahia pedata Gray	NA	Bluntscale Bahia
Baileya multiradiata Harv. & Gray	NA	Desert Bahia
Brickellia laciniata Gray	NP	Spiderleaf Brickelbush
Cirsium texanum Buckl.	NP	Southern Thistle
Conyza canadensis (L.) Cronquist var. *glabratus* (Gray) Cronquist	NA	Horseweed
Dyssodia pentachaeta (DC.) Robinson	NP	Parralena, Common Dogweed
Erigeron modestus Gray	NP	Plains Fleabane
Eupatorium greggii Gray	NP	Palmleaf Eupatorium
Gymnosperma glutinosum (Spreng.) Less.	NP	Tatalencho
Haploesthes greggii Gray var. *texana* (Coult.) I. M. Johnst.	NP	False Broomweed
Helenium quadridentatum Labill.	NA	Rosilla
Helianthus ciliaris DC.	NP	Blue-Weed
Heterotheca fulcrata (Greene) Shinners	NP	Rocky Goldaster
Hymenoclea monogyra T. & G.	NP	Burro-Bush
Hymenoxys scaposa (DC.) Parker	NP	

SCIENTIFIC NAME		COMMON NAME
Isocoma wrightii (Gray) Rydb.	NP	Jimmy-Weed
Iva ambrosiaefolia Gray	NA	Rag Sumpweed
Machaeranthera scabrella (Greene) Shinners	NP	
Machaeranthera wrightii (Gray) Cronq. & Keck	NP	
Melampodium leucanthum T. & G. var. *leucanthum*	NP	Plains Blackfoot
Parthenium confertum Gray	NP	Guayule, Rubber-Plant
Parthenium incanum H.B.K.	NP	Mariola
Pectis papposa Harv. & Gray	NA	Many-Bristle Pectis
Perezia wrighii Gray	NP	Brownfoot
Perityle parryi Gray	NP	Heartleaf Perityle
Perityle vaseyi Coult.	NP	Margined Perityle
Porophyllum scoparium Gray	NP	
Psilostrophe tagetina (Nutt.) Greene	NP	Woolly Paperflower
Senecio douglasii DC. var. *jamesii* (T. & G.) Ediger	NP	Threadleaf Groundsel
Solidago altissima L.	NP	Tall Goldenrod
Sonchus asper (L.) Hill	IA	Prickly Sowthistle
Stephanomeria pauciflora (Torr.) A. Nels.	NP	Desert Skeletonplant
Thelesperma megapotamicum (Spreng.) Ktze.	NP	
Trixis californica Kellogg	NP	American Trixis
Verbesina encelioides (Cav.) Gray	NP	Cowpen Daisy
Viguiera dentata (Cav.) Spreng.	NP	Sunflower Goldeneye
Viguiera stenoloba Blake	NP	Resin-Bush
Zexmenia brevifolia Gray	NP	Shorthorn Zexmenia

APPENDUM TO THE FRESNO CANYON VEGETATION SURVEY

A SEASONAL COMPARISON

Mary Butterwick and Jim Lamb

Information included in this appendum was based on field studies carried out between September 29 and October 2, 1975. The purpose of the fall survey was to observe and record any seasonal changes as a means of comparison with the data gathered the previous summer. Since most of the annual precipitation in this region occurs in August and September, particular attention was paid to possible effects of rainfall on the different plant associations. This task was accomplished through incidental collecting, with emphasis on species not found during the summer. In addition, each of the established transect sites was revisited and fall data were obtained (see section on Methods). The transects sites were accurately relocated. However, the positioning of the 100-m tape was impossible to duplicate. Because of the inherent variability of this sampling technique, the transect data frequently showed a slightly different composition of the grass, herb, and shrub components from that seen in the summer transect data. Although exact comparisons were not feasible, general trends did present themselves and will be elaborated on in the following discussion. For clarity, the plant associations will be discussed separately.

THE SLOPE ASSOCIATION

Transect data obtained from Fresno Canyon showed trends similar to those of the Solitario in the vegetation. For instance, both slope transects showed Total Raw Coverage values of 69.96% and 74.26%, increases of 26.2% and 38.19% respectively (Tables 1, 3). As in the Solitario, the grasses proved most responsive to the seasonal rains. The response was particularly noticeable on a relatively undisturbed slope where grass cover more than doubled from 17.11% to 37.8% (Table 3). *Heteropogon contortus, Bouteloua curtipendula,* and *Bouteloua ramosa* remained dominant grasses. In addition, the presence of *Aristida adscensionis, Bouteloua barbata, Trichachne californica,* and *Tridens muticus* was recorded. *Gymnosperma glutinosum* and *Xanthocephalum microcephalum* were notable examples of fall-flowing Compositae that frequented the slopes of the Fresno Canyon area.

The topography characterizing this association may partially account for the responses found due to climatic changes. Here numerous niches and crevices provide for the accumulation of small quantities of water. This supply of moisture during seasonal rains stimulates both germination of annuals and rapid growth from perennial root stocks. Additionally, the relative inaccessibility of the slopes to grazing livestock functions to preserve the potential for a higher diversity of grasses, given the proper moisture conditions.

THE ALLUVIAL-GRAVEL ASSOCIATION

Data from transects representative of the Alluvial-Gravel Association were consistent with summer findings. Total Raw Coverage varied little from 55.42% to 56.62%. Grasses accounted for only 2.47% of the total coverage, with *Erioneuron pulchellum* still the dominant species. *Larrea tridentata,* a characteristic shrub of this association, showed a relative dominance of 55.15% which is slightly less than the summer value of 60.19% (Table 2).

The Alluvial-Gravel Association has been subject to intense grazing pressure, as evidenced by the predominance of shrubs and corresponding paucity of grasses. These level plains are frequently dissected by a system of minor drainages which facilitate rapid runoff of any water that has not already percolated through the soil. Maximum exposure to sunlight enhances evaporation of any surface moisture. The result is a limited water supply for plants having relatively shallow root systems, even under conditions of ample rainfall. These physical features, combined with the impact of continued grazing, have diminished this association's potential for rejuvenation in response to seasonal climatic changes.

THE CANYON ASSOCIATION

The fall rain left a noticeable impact both on Arroyo Segundo and Chorro Canyon. In Chorro Canyon the luxuriant growth of *Typha latifolia, Equisetum laevigatum* and *Cladium jamaicense* had been crushed and leveled by the current's force.

Gravel-filled pools and a scarcity of herbaceous species remaining on the canyon floors were other signs of a recent flood. In addition to the fall flowering compositae mentioned previously, *Baccharis glutinosa, Eupatorium solidaginifolium,* and *Solidago altissima* frequented the more protected areas of the canyons.

RARE PLANTS

Lycium berberioides or silvery wolfberry was encountered on a line transect along Fresno Creek (Table 4). Only a few individuals were observed at this locality. However, larger populations have been observed from Big Bend National Park. Distinguished from other species of the genus by its glabrous glaucous-grey leaves, this *Lycium* is endemic to Brewster County and the eastern portion of Presidio County.

Cucurbita digitata was collected along the road leading to the Smith House on Fresno Creek. A climbing vine featuring scabrous narrowly digitate leaves, it is particularly noticeable when bearing the hard subglobose gourds that are green with lighter longitudinal stripes. *Cucurbita digitata* apparently has never been collected in Texas. There is no mention of the species in the *Manual of the Vascular Plants of Texas.* This gourd is known elsewhere, from Arizona, New Mexico, and Sonora, Mexico. The isolated locality for *Cucurbita digitata* in Texas is indicative of a relic population. However, the apparent geographical separation may be a function of the scarcity of collections from this region rather than a natural disjunction.

FALL TRANSECT DATA

TABLE 1
Quadrat Transect 9

	Q	RFi	RFii	RDii	TI	RC	RDii	TA
GRASSES								
Aristida wrightii	11	22	6.55	9.34	27	2.34	3.55	117
Bouteloua barbata	2	4	1.19	0.69	2	0.16	0.24	8
Bouteloua ramosa	12	24	7.14	5.88	17	5.24	7.94	262
Erioneuron pilosum	1	2	0.60	0.35	1	0.30	0.45	15
Erioneuron pulchellum	1	2	0.60	0.35	1	0.20	0.30	10
Setaria leucopila	2	4	1.19	2.08	6	1.40	2.12	70
Trichachne californica	6	12	3.57	2.08	6	1.70	2.58	85
Tridens muticus	4	8	2.38	2.08	6	0.96	1.45	48
HERBS								
Agave lecheguilla	7	14	4.17	3.11	9	2.80	4.24	140
Allionia incarnata	12	24	7.14	6.23	18	3.26	4.94	163
Argythamnia neomexicana	2	4	1.19	1.38	4	0.30	0.45	15
Bahia absinthifolia	33	66	19.64	30.80	89	12.68	19.22	634
Cevallia sinuata	1	2	0.60	0.35	1	0.80	1.21	40
Chamaesaracha coniodes	4	8	2.38	1.73	5	0.44	0.67	22
Croton pottsii	4	8	2.38	2.77	8	0.50	0.76	25
Dyssodia pentachaeta	1	2	0.60	0.35	1	0.10	0.15	5
Echinocereus sp.	2	4	1.19	0.69	2	1.40	2.12	70
Herissantia crispa	1	2	0.60	9.35	1	0.30	0.45	15
Iva ambrosiaefolia	28	56	16.67	17.30	50	10.56	16.01	528
Jatropha dioica	5	10	2.98	2.08	6	1.10	0.67	55
Mentzelia multiflora	1	2	0.60	0.35	1	0.60	0.91	30
Parthenium confertum	1	2	0.60	0.35	1	0.30	0.45	15
Phaseolus wrightii	1	2	0.60	0.35	1	0.10	0.15	5
Ruellia parryi	1	2	0.60	0.35	1	0.50	0.76	25
Sida filicaulis	1	2	0.60	0.35	1	0.10	0.15	5
Talinum aurantiacum	2	4	1.19	0.69	2	0.40	0.61	20
Tidestromia lanuginosa	2	4	1.19	0.69	2	0.32	0.48	16
Verbena neomexicana	1	2	0.60	0.35	1	0.04	0.06	2
SHRUBS								
Aloysia wrightii	3	6	1.79	1.04	3	0.80	1.21	40
Celtis pallida	1	2	0.60	0.35	1	0.20	0.30	10
Larrea tridentata	6	12	3.57	2.08	6	6.50	9.85	325
Opuntia imbricata	1	2	0.60	0.35	1	0.60	0.91	30
Opuntia leptocaulis	1	2	0.60	0.35	1	0.70	1.06	35
Porlieria angustifolia	1	2	0.60	0.35	1	2.00	3.03	100
Prosopis glandulosa	4	8	2.38	1.38	4	5.66	8.58	283
Viguiera stenoloba	1	2	0.60	0.35	1	0.30	0.45	15
Ziziphus obtusifolia	1	2	0.60	0.35	1	0.30	0.45	15
TOTALS	168		100.08%	100.07%	289	65.96%	99.93%	3298%

FALL TRANSECT DATA

TABLE 2
Quadrat Transect 10

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Bouteloua eriopoda	6	20.00	8.33	11.41	21	0.40	0.71	12
Erioneuron pulchellum	17	56.67	23.61	21.19	39	1.87	3.30	56
HERBS								
Bahia absinthifolia	21	70.00	29.17	44.02	81	13.53	23.90	406
Echinocereus sp.	1	3.33	1.39	0.54	1	1.33	2.35	40
Iva ambrosiaefolia	7	23.33	9.72	7.06	13	2.53	4.47	76
Pectis papposa	1	3.33	1.39	3.26	6	1.00	1.77	30
SHRUBS & TREES								
Fouquieria splendens	2	6.66	2.78	1.09	2	0.83	1.47	25
Larrea tridentata	13	43.33	18.06	8.70	16	31.23	55.15	937
Opuntia leptocaulis	3	10.00	4.17	2.17	4	1.57	2.77	47
Prosopis glandulosa	1	3.33	1.39	0.54	1	2.33	4.12	70
TOTALS	72		100.01%	99.98%	184	56.62%	100.01%	1699%

TABLE 3
Quadrat Transect 11

	Q	RFi	RFii	RDi	TI	RC	RDii	TA
GRASSES								
Aristida adscensionis	14	28	7.22	7.46	32	2.34	3.15	117
Aristida wrightii	2	4	1.03	0.47	2	1.10	1.48	55
Bothriochloa saccharoides	2	4	1.03	0.47	2	0.40	0.54	20
Bouteloua barbata	1	2	0.52	0.23	1	0.06	0.08	3
Bouteloua curtipendula	15	30	7.73	6.53	28	6.60	8.89	330
Bouteloua ramosa	21	42	10.82	7.93	34	13.16	17.71	658
Erioneuron pulchellum	1	2	0.52	0.23	1	0.06	0.08	3
Heteropogon contortus	28	56	14.43	18.18	78	12.36	16.64	618
Trichachne californica	4	8	2.06	0.93	4	0.50	0.67	25
Tridens muticus	2	4	1.03	0.93	4	1.20	1.62	60
HERBS								
Agave lecheguilla	17	34	8.76	7.46	32	10.50	14.14	525
Bahia absinthifolia	38	76	19.59	33.80	145	8.40	11.31	420
Bahia pedata	1	2	0.52	0.23	1	0.20	0.27	10
Cevallia sinuata	6	12	3.09	1.40	6	3.40	4.58	170
Chamaesaracha coniodes	1	2	0.52	0.23	1	0.10	0.13	5
Croton pottsii	14	28	7.22	4.20	18	3.20	4.31	160
Dasylirion texanum	1	2	0.52	0.23	1	0.30	0.40	15
Dyssodia pentachaeta	1	2	0.52	0.93	4	0.10	0.13	5
Echinocereus pectinatus	1	2	0.52	0.23	1	0.20	0.27	10
Euphorbia antisyphilitica	9	18	4.64	3.96	17	5.40	7.27	270
Euphorbia arizonica	1	2	0.52	0.23	1	0.06	0.08	3
Herissantia crispa	1	2	0.52	0.23	1	0.06	0.08	3
Iva ambrosiaefolia	1	2	0.52	0.23	1	0.20	0.27	10
Jatropha dioica	2	4	1.03	0.93	4	1.50	2.02	75
Macrosiphonia macrosiphon	1	2	0.52	0.23	1	0.50	0.67	25
Ruellia parryi	5	10	2.58	1.17	5	0.60	0.81	30
SHRUBS								
Opuntia phaeacantha	4	8	2.06	0.93	4	1.76	2.37	88
TOTALS	194		100.04%	99.98%	429	74.26%	99.97%	3712%

FALL TRANSECT DATA

TABLE 4
Line Transect 2

	RDi	TI	RDii	TA
Acacia greggii	24.67	37	23.43	49.25
Aloysia wrightii	.67	1	.48	1.00
Celtis pallida	16.00	24	17.72	37.25
Condalia hookeri	.67	1	.59	1.25
Dicraurus leptocladus	2.67	4	2.62	5.50
Larrea tridentata	24.00	36	21.98	46.20
Lycium berberioides	1.33	2	2.14	4.50
Lycium berlandieri	2.67	4	2.62	5.50
Opuntia imbricata	.67	1	.24	.50
Opuntia leptocaulis	.67	1	.24	.50
Opuntia phaeacantha	1.33	2	1.90	4.00
Porlieria angustifolia	14.00	21	12.37	26.00
Prosopis glandulosa	6.00	9	9.52	20.00
Trixis californica	.67	1	.24	.50
Viquiera stenoloba	2.00	3	1.31	2.75
Ziziphus obtusifolia	2.00	2	1.90	5.50
TOTALS	**100.02%**	**150**	**99.30%**	**210.20%**

APPENDUM TO FRESNO CREEK SPECIES LIST

A — Annual
P — Perennial
I — Introduced
N — Native
*** — Endemic or Rare**

POLYPODIACEAE		TRUE FERN FAMILY
Cheilanthes horridula Maxon	NP	Rough Lipfern
Cheilanthes wrightii Hook	NP	Wright Lipfern
POLYGONACEAE		KNOT WEED FAMILY
Persicaria vulgaris Webb & Moq.	IA	Lady's Thumb, Moco De Guajolote
AMARANTHACEAE		AMARANTH FAMILY
Dicraurus leptocladus Hook f.	NP	
NYCTAGINACEAE		FOUR O'CLOCK FAMILY
Commicarpus scandens (L.) Standl.		Climbing Wart-Club, Pega-Polla
Mirabilis coahuilensis (Standl.) Standl.	NP	Four O'Clock
PORTULACACEAE		PURSLANE FAMILY
Talinum aurantiacum Engelm.	NP	Flame Flower
EUPHORBIACEAE		SPURGE FAMILY
Euphorbia arizonica Engelm.	NP	
Euphorbia serpens H.B.K.	NA	Hierba De La Golondrina
ONAGRACEAE		EVENING PRIMROSE FAMILY
Oenothera brachycarpa Gray	NP	Evening Primrose
OLEACEAE		OLIVE FAMILY
Menodora decemfida (Gill) Gray var. *longifolia* Steyerm.	NP	Tenfinger Menodora
VERBENACEAE		VERBAIN FAMILY
Tetraclea coulteri Gray	NP	
SOLANACEAE		NIGHTSHADE FAMILY
Chamaesaracha conoides (Dun.) Britt	NP	False Nightshade
**Lycium berberioides* Correll	NP	Silvery Wolf Berry
Physalis lobata Torr.	NP	Purple Ground Cherry
PLANTAGINACEAE		PLANTAIN FAMILY
Plantago major L.	IP	Common Plantain, Lantin
CUCURBITACEAE		GOURD FAMILY
**Cucurbita digitata* Gray	NP	
COMPOSITAE		SUNFLOWER FAMILY
Aster subulatus Michx.	NA	Hierba Del Marrano
Eupatorium solidaginifolium Gray	NP	Shrubby Eupatorium
Gnaphalium wrightii Gray	NA	Cud Weed
Thelesperma simplicifolium Gray	NP	Green-Thread

RANGES AND RANGE MANAGEMENT IN THE FRESNO CANYON AREA

C. Wayne Hanselka

Increasing demands on natural resources have forced a reevaluation of the traditional uses of land. Various surveys have shown that the rangelands of North America are currently producing less than half of the products they once were capable of producing. A rising standard of living plus an increased population have placed added pressures for food, fiber, and recreation on rangelands. These pressures cannot be ignored and should give impetus to developing and managing rangelands to their fullest capabilities.

The Chihuahuan Desert of Southwest Texas is a large range area that historically has been neglected from the standpoint of range management. Most of the Big Bend region (which is part of the desert) has been grazed for nearly a century, and much has been overgrazed. Moreover, Big Bend National Park is attracting more people each year to Southwest Texas, and there are demands for the development of recreational areas outside of the national park.

Hunting leases are taken up at least a year ahead of the hunting season. Sport hunting for mule deer (*Odocoileus hermonius*), javelina (*Tajacu tajacu),* scaled quail (*Callipepla squamata*), and mourning dove (*Zenaidura macroura*) is a source of supplemental income for most land-owners in this region.

Nevertheless, the primary land-use in the Chihuahuan desert is still the production of food and fiber. Domestic livestock, primarily cattle, is the economic base of the area. The concept of multiple use has been followed in the past and, in view of the above, must be expanded in the future. This indicates that a proper management plan must be formulated to utilize fully the range base for these activities. Range management employs ecological knowledge for the protection, improvement, and continued welfare of the range resource with optimum production of goods and services as needed by mankind. To that end, the central objective is to provide forage for domestic and wild animals.

THE STUDY AREA

Fresno Canyon is the drainage area of Fresno Creek in southwestern Presidio County, Texas. The name, in Spanish, means ash trees (*Fraxinus* sp.), indicating a mesic situation. In truth, the drainage separates strata of igneous materials from an area of sedimentary origin, resulting in the exposure of water sources in the form of springs and seeps. Near these springs the vegetation is composed of typically mesic species, i.e., species requiring moderate amounts of water. Riparian shrubby vegetation dominates the *arroyos* and draws where water is not readily available. Upland areas are covered with typical Chihuahuan desert shrub associations. Grasses are abundant, particularly on the hillsides.

The climate is semiarid to arid with a mean of less than 208 mm of annual precipitation. The summer months are dry with occasionally convective thunderstorms. Most of the annual precipitation is received in the late summer and autumn months. The area is subject to flash flooding when adjacent areas receive precipitation.

Mean summer temperatures may be over 40°C. Winter temperatures are mild, although nocturnal freezing temperatures may occur.

The area under consideration includes ranges adjacent to and in Fresno Canyon, bounded by the Solitario rim on the east, the Rio Grande bolsons to the south; and the Bofecillos Mountains to the west and north. The area encompasses approximately 6656 hectares (16,640 acres).

RESULTS AND DISCUSSION

Range Sites

One of the basic concepts in range management is that of the range site. Differing combinations of ecological factors (topography, soil, drainage, etc.) affect an area's capacity to produce vegetation. The kind and amount of vegetation on one site will differ from the kind and amount produced on adjacent sites.

Five basic range sites were delineated in the Fresno Canyon area. These were (in order of decreasing size): (1) igneous mountain and hill, (2) gravelly outwash, (3) limestone mountains and hills, (4) draw, and (5) clay flat (Fig. 1).

(1) The igneous hill and mountain sites occur as

rough broken hills and mountains with a range of 30% or more slope. Soils are very shallow, stony loams over igneous bedrock and cover less than 20% of the surface. The soil taxonomic unit is Brewster stony loam. Climax vegetation is a mixture of short and mid grasses, numerous shrubs, and frequent forbs. Brush and cacti increase as retrogression occurs. This site occurs extensively in the western and southern portions of the study area.

(2) Alluvial fans, along *arroyos* and below hills, comprise the gravelly outwash sites. Canutio cobbly loams, Canutio gravelly, sandy loam, and Bluepoint gravelly sands characterize the site. A sparse cover of grasses, shrubs, and annual forbs is found in the climax vegetation. Desert shrubs dominate deteriorated gravelly sites.

(3) Limestone hill and mountain sites occur as rolling hills and steep mountains of limestone origin. Slopes are generally from 8% to 30%. Lozier gravelly loam soils characterize this site. They are very shallow stony and gravelly loams having 60% stone or gravel on the surface and in the profile. Climax vegetation is a grassland with associated shrubs and forbs. Shrubby vegetation increases with deterioration. This site is important in the northeast portion of the study area.

(4) The draw sites are narrow, overflow areas that receive runoff water from adjoining sites. They are usually flat with slopes of 1% or less. Soils are in the mimbres loam unit and are of a deep, calcareous alluvial nature. Short and midgrasses compose the climax vegetation. Shrubs are associates that invade and increase as the grasses are removed.

(5) A clay flat site is located on the west side of Fresno Canyon. It is nearly level but does contain occasional rolling hills. It is deeply scarred by erosion-caused gullies. Soils are deep, silty clay loams. Climax vegetation is characterized by short grasses and forbs. Retrogression allows low quality grasses to increase. Perennial forbs and some woody plants also increase or invade.

Range Condition

The condition of a range site is measured by determining plant species composition at the present and comparing this with species in the climax vegetation. Four condition classes of range are based upon these measurements. These are:

Excellent: 76-100% of the climax species are present now.

Good: 51-75% of the present composition are climax species.

Fair: 26-50% of the present composition are climax species.

Poor: 0-25% of the present composition are climax species.

Utilizing this method, I determined the Fresno Canyon study area to be in low fair condition.

The igneous hill and mountain site is concentrated in the higher, steep mountains segment to the west of Fresno Creek. In the southern portion of the area there are some low igneous hills to the east of the creek. Overall, the site is in high poor condition. Low quality three-awns (*Aristida* sp.) and Chino grama (*Bouteloua breviseta*) are the dominant grasses. Leatherstem (*Jathropha spathulata*) and various species of cacti (*Opuntia* sp.) are prominent components of the hillside vegetation. Many perennial and annual forbs are associates.

Based on species composition and production, this site can carry approximately an animal unit (A.U.) on each 64 hectares under year-long grazing. An animal unit is the equivalent of a mature cow with calf.

Many *arroyos* and draws comprise the drainage system of the area. The primary draws are Fresno Creek, Arroyo Primero, and Arroyo Segundo. Secondary draws and drainages are the lefthand shutup and an unnamed shutup from the Solitario to the east of Fresno Creek. Numerous springs and intermittent flowing water occur along these drainages. The low, fairly level terrain and the availability of water have resulted in severe overgrazing. No desirable grass species were recorded on the draw sites. Climax shrubs composed 13.7% of the plant composition and allowable forbs contributed 2.0%. The remaining 84.3% were invader or increaser species. This places the draw sites in a poor classification. The draws will support only an A.U. on every 72 hectares (180 acres) over an annual period.

An exception to this is in Arroyo Primero along the Chorro Canyon drainage. Abundant water has allowed localized lush vegetation to thrive. Horsetails (*Equisetum* sp.) and cattail (*Typha* sp.) provide forage for livestock and thus could raise the carrying capacity. However, this area is so localized and fragile that I am excluding it from this analysis.

The limestone hills and mountains site is not used as severely as the other sites in Fresno Canyon. This site occurs on the steep area of the northeast portions of the canyon at the base of the Solitario rim. It is in fair condition with 39.7% of the plant species present found in the climax. This is the result of inaccessibility to livestock and distance from drinking water. The site in this condition can support an A.U. on every 40 hectares (100 acres).

The clay flat site is almost devoid of desirable vegetation. Total climax species account for less than 8% of the composition. Consequently, the site is in low poor condition. Creosote bush (*Larrea divaricata*) dominates the area. The clay flat carrying capacity is in excess of an A.U./85.2 hectares (213 acres) for a year. There is no water on this site.

Gravelly sites are limited in Fresno Canyon. This site is usually found around the base of hills and mountains and gravel fill between the peaks at higher elevations. It is in the best condition of all the sites in the area. Almost half of the species on this site are desirable, climax species allowing the site to be placed in high fair condition. Grasses (11%), shrubs (15%) and forbs (19%) contribute to this total. On this basis, the site can support an A.U. on each 44 hectares (110 acres).

The Fresno Canyon area as considered here has an area of approximately 6656 hectares. Based on size plus the condition classes and stocking rates outlined above, it is estimated that the area has a carrying capacity of 125 A.U.'s. Topography is not considered, however, so actual grazing capacity is somewhat lower. If good animal distribution could be achieved the area around Fresno Canyon could be stocked at an A.U./53 hectares/year-long (1 A.U./133 acres).

Water is available along the drainages but is not properly distributed away from the draws. This unequal distribution has resulted in unequal grazing pressure in the past and would affect the carrying capacity of the range at the present.

Range Improvements

Fencing, and thus animal control, is inadequate in managing the ranges of Fresno Canyon. Only one fence is effective in the drainage area, with one more in the upland area. Other fences are in disrepair and are ineffective.

Water distribution is perhaps the most important consideration in this portion of Texas. Watering areas would need to be constructed in the upland areas. There is sufficient water in the drainages. The clay flat site is so deteriorated that the expense of providing water on this site would not be justified.

SUMMARY AND CONCLUSIONS

The Fresno Canyon drainage area is a 6656-hectare area in southeastern Presidio County. Five range sites are delineated on the area. The range has been severely overutilized in the past so that most of the sites are in poor condition today. On the basis of vegetative composition it is estimated that the area could support 125 A.U.s, but actual capacity is probably somewhat lower due to topography and unequal water distribution. Management could be enhanced with the addition of effective fencing and better water distribution.

VERTEBRATE FAUNA OF THE FRESNO CANYON AREA

James F. Scudday

The Fresno Canyon area, as used in this report, includes the major drainages into upper Fresno Canyon, Arroyo Primero including Chorro Canyon, and Arroyo Segundo. Chorro Canyon is a short drainage that empties into Arroyo Primero about one mile upstream from the junction of Arroyo Primero with Fresno Creek. Although short, Chorro Canyon is of special interest because two beautiful waterfalls are located in its upper end, one about 30 feet in height and the other about 100 feet in height. Water flows in Chorro Canyon the year around, providing a truly singular beauty spot within the surrounding desert.

There have been few published accounts of biological investigations into the upper Fresno Canyon area prior to 1970. Davis (1966) makes one reference to the Fresno area with regard to a single specimen of a Mastiff Bat reported from the Fresno Mine. Two earlier published works from the La Mota Mountain area just to the north of Fresno Canyon constitute the only published accounts of vertebrate animals from the close vicinity. Milstead (1953) reported on the ecological distribution of the lizards of La Mota Mountain, and Tamsitt (1954) compared the mammalian fauna of La Mota Mountain with that of the nearby Black Gap area of Brewster County. More recently, Olson (1973) conducted a taxonomic study on *Sceloporus merriami* in the Closed Canyon area to the south of the study area and on San Jacinto Mountain to the north of the study area, but he did not visit Fresno Canyon.

Dr. A. M. Powell of Sul Ross State University and Dr. Marshall Johnston of The University of Texas at Austin have made some plant collections in the area since 1970. I began visiting the area in 1970, making collections and observations of the vertebrate fauna. John Burns (1976) conducted an ecological study of Chorro Canyon June 1974-May 1976. Scientists of several disciplines, including biologists, from the General Land Office have been investigating the Fresno Canyon ecosystem since 1973, and I have assisted them on several occasions. Mike McKann (1975) has recently completed a thesis on the recreation potential of Chorro Canyon. McKann's thesis contains appendices listing the various classes of vertebrates documented or expected from the Chorro Canyon-Fresno Canyon area. His species lists were partially compiled from my existing data and data secured by the General Land Office team up to 1974.

General Land Office biologist Rose Ann Rowlett conducted seasonal surveys of the birds of the Chorro-Fresno Canyon. Her data, combined with my data (1976), and that provided by Susann Winckler, gives a more complete record of the avifauna of the area than was possible in most previous Texas Natural Areas Surveys.

Most recent effort in zoological sampling has been applied to the area between the Fresno Creek junctures of Arroyo Primero and Arroyo Segundo, with the old Smith Ranch building complex in the center, and in Chorro Canyon. Arroyo Segundo and the area along Fresno Creek from the mouth of Arroyo Primero to the old Fresno Mine received less study. A single exploratory trip was made to the east between Fresno Creek and the Solitario. Fresno Creek from the old Fresno Mine to its confluence with the Rio Grande was not investigated at all.

Fresno Canyon and its associated drainage system represent one of the most diversified desert ecosystems within the state of Texas. Several factors have contributed to the development of such a varied biota within this north central portion of the great Chihuahuan Desert. An important factor is the physical diversity of the terrain itself. A relatively smooth-surfaced sotol-grassland may suddenly break over a bluff into steep-sided canyons that grade onto gravelly, creosote bush lowlands 900 m below, all over an airline distance of less than 1 km. Within that distance of 1 km, a dozen plant communities may be telescoped between the two extremes. The sharp breaks in the strata have in turn interdicted water tables sandwiched between basaltic and tuffaceous layers, providing an unusual abundance of springs, seeps, and, ultimately, intermittently running streams along the canyon floors.

That water has flowed in these canyons for millenia is attested to by the presence of relictual species, survivors from a past when the entire region was much more mesic than it is today. At the present only the main drainage and some of its tributaries support a narrow belt of truly riparian habitat with its attendant gallery forest of cottonwoods, ash, and willow, a habitat missing in much of the Chihuahuan Desert. Such areas are true oases and biologically serve as centers of concentration for animals with a high degree of mobility, such as flying organisms (birds, bats, and insects) that can find and colonize such areas in the midst of inhospitable terrain. This is particularly important during times of mass movements such as seasonal migrations.

Even among desert-adapted animals there are species that require the availability of free water. This is the case with most large mammals such as carnivores and artiodactyls, as well as with almost all bird species. Add this variety of life to those species so adapted to desert environments that they can exist regardless of water being available, and a greatly diverse assemblage of fauna results.

Well-defined habitat preferences are exhibited by most vertebrate species within the study area, especially of relictual species and those species not considered strictly Chihuahuan. Some species are ubiquitous and are found in every kind of habitat throughout the Chihuahuan Biotic Province (Blair 1950).

The kinds of relict spceies in the Chihuahuan Desert and their significance in terms of clues to past environments of the region were discussed by Milstead (1960). Two important relictual species occurring in the Fresno Canyon area are the Trans-Pecos Copperhead and the Madrean Cliff Frog. A third species, the Canyon Treefrog, has shown a greater degree of adaptation to a drying environment and thereby has morphologically diverged away from its ancestoral form more than have the copperhead and cliff frog. For this reason, it is not considered strictly relictual, although its origins are similar to those of the other two. All three of these species are confined to the riparian corridors and deep, shaded mesic canyons.

Because of its physiographic features and locality near the Mexican Highlands, the Fresno Canyon area is within the most northward distributional range of a number of typically Mexican species. This includes at least five bats, four birds, four reptiles, and one amphibian. Some of these species are rare even in Mexico, and their peripheral occurrence in the United States within the study area is significant. At least one species of reptile, The Big Bend Gecko (*Coleonyx reticulatus*), is known to occur only in this part of Presidio County and neighboring southwestern Brewster County.

There are no fish in any of the streams or springs within the study area although the Rio Grande is only 12 miles away. Historically, fish may have extended up Fresno Creek for some distance, and it will be interesting to see if archeological investigations reveal that fish once occurred this far from the Rio Grande. Continued drying conditions and periods of extreme drought in the southwest have eliminated the fish fauna from most of the tributaries of the Rio Grande in southwest Texas. The intermittent character of Fresno Creek today precludes the movement of fish into its upper reaches.

Other kinds of disasters to fish populations probably also have occurred. Flash floods can be disastrous to fish in their scouring and silt-filling effect on pools and alteration of stream courses. The deep channels and pools of water in Chorro Canyon appear especially well suited to some form of fish fauna until one views the destructive force of the tremendous volume of water that can be generated by a three-quarter-inch downpour of rain in the canyon. Flash floods are a hazard that all forms of life must contend with in the canyon country of the Rio Grande drainage. Only last year (1974) a human life was lost to a flash flood in Arroyo Segundo.

I am grateful to a number of persons for assistance in field work and data gathering for this report. Dr. Wayne Hanselka of Sul Ross State University and members of my Field Zoology class were especially helpful in conducting field investigations during the summer of 1975. Rose Ann Rowlett, Mike McKann, and Susann Winckler of the General Land Office graciously furnished me their data on the area. John Burns (1976) made his data on Chorro Canyon available to me. I have utilized the Vertebrate Collection of Sul Ross State University (SRSU), and all voucher specimens collected from the study area are deposited in that collection.

The format for this report provides a list of vertebrates of each class known to occur within the study area (based upon voucher specimens within a collection or observations in the field), followed by a discussion of pertinent facts related to each class. In a few instances, a species is included solely on the basis of circumstantial evidence. Each of these and the reason for its inclusion will be covered in the discussion section of each class. The discussion will not necessarily cover every species listed. Most species listed are typically Chihuahuan species to be expected within the study area and do not represent any unusual record or pose any special biological problem.

Common names of amphibians and reptiles are those used by Thomas (1974). Common names of birds are according to the AOU Checklist of North American Birds (1957) and its recent supplements. Most mammalian common names are after Davis (1966). Scientific names are used in all the lists, except for the bird list, and may be used in the text where confusion may result. Generally, where a scientific name is matched with the common name in the lists of documented species, the common name only is used in the text.

AMPHIBIANS OF THE FRESNO CANYON AREA

CLASS AMPHIBIA

Order Anura	
Family Pelobatidae	*Scaphiopus* couchi – Couch's Spadefoot
	S. hammondi – Western Spadefoot
Family Leptodactylidae	*Syrrhophus guttilatus* - Madrean Cliff Frog
Family Bufonidae	*Bufo debilis* – Green Toad
	B. punctatus – Red-spotted Toad
	B. speciosus – Texas Toad
Family Hylidae	*Hyla arenicolor* – Canyon Treefrog
Family Microhylidae	*Gastrophryne olivaceae* – Great Plains Narrow-mouth Toad
Family Ranidae	*Rana berlanderi* – Rio Grande Leopard Frog

DISCUSSION

The mesic situation along Fresno Creek and some of the nearby canyons has allowed the development of a habitat suitable for a diverse amphibian fauna. Although amphibians are not plentiful by most standards, the diversity of the amphibian fauna here within a desert ecosystem is impressive. Six families of anurans are represented by 10 species, with two species considered relict species. No caudates have been recorded from the area. The Tiger Salamander (*Ambystoma tigrinum*) is the only caudate recorded for all of Trans-Pecos Texas, and it has been taken from near Lajitas. The species apparently has not been successful in invading the flash-flood prone canyon streams.

Spadefoots (*Scaphiopus*) are one of the most desert-adapted amphibians in the arid southwest. Couch's Spadefoot prefers the creosote hills of the lower desert, while the Western Spadefoot occurs more often in the grassy highlands. The Sul Ross collection contains specimens of Couch's Spadefoot from near the Fresno Mine and specimens of the Western Spadefoot from the Bandera Ranch, about 10 miles northeast of Fresno Canyon. The Western Spadefoot is included here because of the similarity of habitat of the higher grassland above Fresno Canyon with that of the nearby Bandera Ranch.

The Madrean Cliff Frog is included among the Fresno Canyon fauna on the basis of known specimens from the mine at Villa de la Mina and from upper Alamito Creek, areas to the southeast and northwest of the study area. This rare little frog is certain to occur in Chorro Canyon. Habitat there appears to be ideal. Extreme secretivness is the rule with the cliff frog, and it is sometimes discovered in areas only after intensive investigations have been conducted. These tiny frogs call only when climatic conditions, especially humidity, are just right. They are sometimes recorded for areas on the basis of aural evidence, without being seen. Bufonids (true toads) are the most common amphibians of the Fresno Canyon area. Red Spotted toads were common in the creek beds of the area during all spring and summer months. Green Toads were found only one time, in a cement trough at the spring, approximately one mile up Fresno Creek from the Fresno Mine.

Canyon Treefrogs were found in Chorro Canyon and in Arroyo Segundo. This desert-adapted species is confined to deep mesic canyons of the southern Trans-Pecos Region. Canyon Treefrogs may be abundant in times of rainfall when the canyon floors are running fresh water but are almost impossible to find during prolonged dry periods. More needs to be learned about the biology of this desert-dwelling treefrog.

REPTILES OF THE FRESNO CANYON AREA

CLASS REPTILIA

Order Squamata

Suborder Lacertilia

Family	Species
Family Geckkonidae	*Coleonyx* brevis – Texas Banded Gecko
	C. reticulatus – Big Bend Gecko
Family Igaunidae	*Crotaphytus collaris* – Collared Lizard
	Cophosaurus texana – Greater Earless Lizard
	Phrynosoma cornutum – Texas Horned Lizard
	P. modestum – Round-tailed Horned Lizard
	Sceloporus poinsetti – Crevice Spiny Lizard
	S. undulatus – Southern Prairie Lizard
	S. merriami – Canyon Lizard
	S. magister – Twin-spotted Spiny Lizard
	Uta stansburiana – Side-blotched Lizard
	Urosaurus ornatus – Tree Lizard
Family Scincidae	*Eumeces obsoletus* – Great Plains Skink
	E. brevilineatus – Short Lined Skink
Family Teiidae	*Cnemidophorus tigris* – Western Whiptail
	C. inornatus – Little Striped Whiptail
	C. septemvittatus – Rusty-rumped Whiptail
	C. tesselatus – Checkered Whiptail

Suborder Serpentes

Family	Species
Family Leptotyphlopidae	*Leptotyphlops dulcis* – Texas Blind Snake
Family Colubridae	*Diadophis punctatus* – Ringneck Snake
	Elaphe subocularis – Trans-Pecos Rat Snake
	E. guttata emoryi – Emory's Rat Snake
	Ficimia cana – Western Hook-nosed Snake
	Lampropeltis mexicana – Gray Banded Kingsnake
	Masticophis flagellum testaceus – Red Racer
	M. taeniatus – Ornate Whipsnake
	Pituophis melanoleucus – Bull Snake
	Salvadora hexilepis – Big Bend Patch-nosed Snake
	S. grahamiae – Mountain Patch-nosed Snake
	Tantilla atriceps – Mexican Black-headed Snake
	T. rubra cucullata – Hooded Black-headed Snake
	Thamnophis cyrtopsis – Black-necked Garter Snake
	Trimorphodon biscutatus vilkinsoni – Texas Lyre Snake
Family Viperidae	*Agkistrodon contortrix pictogaster* – Trans-Pecos Copperhead
	Crotalus atrox – Western Diamondback Rattlesnake
	C. lepidus – Rock Rattlesnake
	C. molossus – Black-tailed Rattlesnake
	C. scutelatus – Mojave Rattlesnake

DISCUSSION

Deserts and reptiles are often considered synonymous, and the Fresno Canyon area of southern Presidio County certainly meets this stereotyped concept. Thirty-three species of reptiles have been documented for the area, and at least five additional species are to be expected. This makes the class *Reptilia* second only to birds in number of species occurring there. Reptiles are the most visible components of the area's verbetrate fauna, being readily seen in all habitats during the warmer months, while birds are most visible only in the riparian habitat. But at least some avian species can be seen in the coldest of winter months when no reptiles are about.

The only habitat not completely occupied by reptilian species is the aquatic habitat, since the only desert reptiles capable of dominating the aquatic habitat are turtles. Turtles, like fish, could theoretically move up Fresno Creek from the Rio Grande, and probably have done so in the past. Turtles may yet be found in the lower end of the creek. However, no turtles have been documented from the upper Fresno Canyon area, probably due to the disastrous floods that sweep the canyons. I suspect the Yellow Musk Turtle (*Kinosternon flavescens*) occurs in isolated stock tanks within the area, and, because of its tendency to move overland in wet times, it should occasionally be found within the canyons themselves.

Although no reptilian species literally lives in the water, the presence of water is an important factor in accounting for the diversity of the reptilian fauna, particularly snakes. The streams and pools have provided a riparian habitat that in turn attracts a variety of suitable prey species upon which snakes can feed. Birds, frogs, and toads are plentiful along the stream courses, and several species of snakes specialize in these food items. Even lizards and other snakes contribute to a complex food web within the canyon ecosystem. Lizards, in turn, find a greater supply of insect prey because of the more mesic situation.

Lizards are by far the most commonly seen vertebrates during the spring and summer months. Several families of lizards are represented by a number of diverse species. With 10 species, the large cosmopolitan family Iguanidae is the largest family represented within the study area.

Of the iguanid lizards, the genus *Sceloporus* is the largest with three documented species and another species to be expected. The small Canyon Lizard (*Sceloporus merriami*) was readily seen along the bluffs and everywhere that sizable rock outcrops occurred. It was always the most visible lizard within the steep-walled canyons. These small rock-dwelling lizards are really quite unique among the herpetofauna of the United States. They occur only along the Rio Grande drainage in Presidio, Brewster, Terrell, and Val Verde counties, Texas. Yet they are often numerous where they do occur.

Two subspecies of the Canyon Lizard have long been recognized in Texas, *Sceloporus merriami merriami* and *S.m. annulatus.* Olson (1973) recently studied variation in the Canyon Lizard and concluded that a third subspecies existed in Presidio County. He named the Presidio County population *S.m. longipunctatus* but recognized a zone of intergradation near the Brewster County line with *S. m. annulatus.* Priest (1972) compared behavorial, as well as morphological, differences between populations of *Sceloporus merriami* from Presidio and Val Verde counties. He found definite variations in the pattern of "challenge" movements. Males courted only females of the same race, indicating a strong trend toward divergence of the two races. The Canyon Lizard is a dynamic species, and the Fresno Canyon area is an ideal outdoor laboratory to study speciation and evolutionary processes in this and other species.

Spiny Crevice Lizards are found in the same habitat as Canyon Lizards. In spite of their large size, few Spiny Crevice Lizards were seen within the study area. It is possible that competitive factors favor the much smaller Canyon Lizard here. In mountains to the north of the study area, Canyon Lizards do not occur, and Spiny Crevice Lizards are much more numerous, being the dominant reptilian cliff dwellers.

The third sceloperine species, the Southern Prairie Lizard, was found on tree trunks in the riparian habitat or around woody shrubs on the hill slopes. It does not appear to be common within the area.

The Twin Spotted Spiny Lizard (*Sceloporus magister*) is a large sceloporine lizard, similar in size to the Crevice Spiny Lizard. It has been taken in creosote desert areas from many localities in southern Presidio County and undoubtedly occurs within the study area, although no specimens were taken or observed.

The family Teiidae is primarily a neotropical family of lizards, reaching its greatest diversity in South America. Only one genus of the family reaches the United States, the genus *Cnemidophorus.* This genus has become especially adapted to living in the desert southwest and has proliferated numerous species to occupy every kind of southwestern habitat.

The phenomenon of reproduction by parthenogenesis has been achieved by several distinctive populations of *Cnemidophorus* within the southwestern U.S., giving rise to all-female species. Parthenogenetic populations arise through hybridization between normal sexual species. Hybrid animals produced through such interspecific crosses are normally sterile. However, an occasional hybrid female *Cnemidophorus* achieves the capability of reproducing by parthenogenesis, thereby circumventing normal hybrid sterility. Why this phenomenon should occur often within some animal groups and not at all in others is not known.

The taxonomic status of hybrid parthenospecies is debatable for some biologists. Several distinct populations of *Cnemidophorus* were described and named long before their parthenogenetic mode of reproduction was discovered. These populations, then, already possessed accepted taxonomic names. The Checkered Whiptail (*Cnemidophorus tesselatus*) is one of these.

All available evidence points to the normal sexual

Cnemidophorus tigris and *C. septemvittatus* as the parental species that hybridized to give rise to the parthenogenetic *C. tesselatus*. Today, *C. tesselatus* and *C. tigris* are found sympatrically throughout much of their range, but *C. septemvittatus* is seldom found with either in a shared range. All three species can be found together in the Fresno Canyon area, making this area of special interest to herpetologists.

Each of the three species involved with parthenogenetic origins is somewhat restricted in the area by their ecological preferences, but in certain situations all three may be found together. The Checkered Whiptail is by far the most prevalent species, occurring in all the roughland habitat. The Western Whiptail prefers the sandy to gravelly stream beds and lower slopes. Rusty-rumped Whiptails are the least common of the three and were generally found only upon the highest slopes. A single specimen, however, was taken from the low, gravelly, lechuguilla-covered hill just east of the Smith Ranch, a habitat much more suitable to the Western Whiptail.

A fourth species of *Cnemidophorus, C. inornatus* was found in a single locality above the western rim of Chorro Canyon. The site was a relatively level deteriorated sotol-grassland area. The *Cnemidophorus* complex of lizards within the study site is another dynamic group that invites detailed investigations into their speciation, ecology, and interrelationships.

The Side-blotched Lizard is usually found in very sandy desert situations. Specimens of the species were collected in the study area along sandy to gravelly arroyos and creek beds. If this is the only place occupied by the species, how does it maintain itself in face of the devastating floods that move down the canyons several times a year?

Two species of horned lizards occur in Fresno Canyon, but neither species appears to be common. Round-tailed Horned Lizards were seen more often than the Texas Horned Lizard in spite of the little, camouflaged Round-tailed Horned Lizards being more difficult to see. Round-tailed Horned Lizards often perfectly color-match the substrate upon which they are found. This small "horny-toad" tends to a dark reddish-brown, the predominant color of the basaltic rocks of the area. A single Texas Horned Lizard was found at the Smith Ranch.

The family Geckonidae is represented by two species of *Coleonyx.* Texas Banded Geckos are common but difficult to find because of their nocturnal habits. Rocks and other suitable hiding places must be turned to find this delicate little lizard during the day. Such hiding places should be returned to their original position after checking for geckos. Although no specimens of the Big Bend Gecko were located, they are included in the herpetofauna here on the basis of known specimens collected on Farm-to-Market Road 170, only a few miles south of the study area. The Big Bend Gecko is an extremely rare species of lizard, presently known only from this area and adjoining southwestern Brewster County.

Over the past three years of biological investigations in the Fresno Canyon area, a long list of snakes occurring there has been compiled. In most instances each species listed is based upon a single known specimen. The most commonly encountered nonpoisonous snake is the Black-necked Garter Snake. These handsome snakes are almost always seen in and around the deeper pools and springs where they search for tadpoles and leopard frogs. They may be found anywhere along the riparian habitat.

Big Bend Patch-nosed Snakes, Ornate Whipsnakes, and Red Racers are common snakes of the more arid habitats. Three rare species of snakes are included within the study area on basis of known specimens from areas of similar terrain and habitat nearby. These are the Gray-banded Kingsnake, Hooded Black-headed Snake, and Texas Lyre Snake. All these forms have been collected within 10 miles of the study area.

Some of the most commonly encountered snakes of the study area were venomous species, and the most commonly encountered venomous snake was the Trans-Pecos Copperhead, a snake considered to be a rare and relictual subspecies (Milstead 1960). This form was often found in the riparian association between the Smith Ranch and Fresno Creek, below the old Madrid Ranch house in Arroyo Primero, and between the two falls in Chorro Canyon. The Trans-Pecos Copperhead is found only in mesic canyons of west Texas.

Black-tailed Rattlesnakes were commonly found in the same habitat as the Trans-Pecos Copperhead at the Smith Ranch, but, unlike the copperhead, they could be found on the drier hill slopes. The Mojave Rattlesnake and the Western Diamondback Rattlesnake prefer the lowland desert habitat. Only one of each of these two species was taken in the study area. The Mojave Rattlesnake is the most venomous of Texas reptiles.

The small Rock Rattlesnake was not actually seen in the study area, but it is known from numerous sites nearby. This small rattler prefers steep talus slopes, and the preferred habitat is abundant in the area. This species is often sought by commercial snake collectors, and has been added to the list of protected species in Arizona.

AVIFAUNA OF THE FRESNO CANYON AREA

The following list of avian species of the Fresno Canyon area was compiled by Rose Ann Rowlett of the Texas General Land Office. Data for compilation of the list were gathered by Rowlett and myself in various vists to the area during different seasons of the year from 1972 to 1974. The list was then used by McKann (1975), with Rowlett's and my permission, for inclusion in his thesis on Chorro Canyon. Susann Winckler added additional observations later in 1975. The list is presented here in much the same form that McKann presented it, with some modifications on my part to accomodate ordinal and familial names and with species that have been added to the area's avifauna since 1974. Because the common names of avian species have become so standardized by the American Ornithologists Union, scientific names of species are omitted. The following code is used to designate the status of each species. S=Summering (late May-August); W=Wintering (November-early March); M=Migrant (Spring-Fall); b=evidence of breeding; X=sight record; e=no record, but expected to occur.

CLASS AVES

SPECIES	ST	WT	M
Order Anseriformes			
Family Anatidae			
Mexican Duck	X		
Cinnamon Teal			X
Order Falconiformes			
Family Cathartidae			
Turkey Vulture	b		X
Family Accipitridae			
Sharp-shinned Hawk	b	e	
Coopers Hawk		e	X
Red-tailed Hawk	b	X	
Swainson's Hawk			X
Zone-tailed Hawk	X		
Ferruginous Hawk		X	
Golden Eagle		X	X
Family Falconidae			
Kestrel		X	
Order Galliformes			
Family Phasinidae			
Scaled quail	X	X	
Order Charadriiformes			
Family Charadriidae			
Killdeer	b	X	
Family Scolopacidae			
Spotted Sandpiper			X
Order Columbiformes			
Family Columbidae			
White-winged Dove	b	X	
Mourning Dove	b	X	X
Ground Dove	X	e	
Order Cuculiformes			
Family Cucilidae			
Yellow-billed Cuckoo	b		
Roadrunner	b	X	
Order Strigiformes			
Family Strigidae			
Barn Owl	e	e	X
Screech Owl	X	e	e
Great Horned Owl	b	X	
Elf Owl	b		
Order Caprimulgiformes			
Family Caprimulgidae			
Poor-Will	b		
Common Nighthawk	b		
Lesser Nighthawk	b		X
Order Apodiformes			
Family Apodidae			
White-throated Swift	b	e	X
Family Trochilidae			
Lucifer Hummingbird	b		
Black-chinned Hummingbird	b		X
Broad-tailed Hummingbird			X
Rufous Hummingbird			X
Order Piciformes			
Family Picidae			
Red-Shafted Flicker	b	X	
Golden-fronted Woodpecker	X	X	
Ladder-backed Woodpecker	b	X	
Yellow-bellied Sapsucker		X	
Order Passeriformes			
Family Tyrannidae			
Western Kingbird	b		
Ash-throated Flycatcher	b		
Western Flycatcher	b		
Empidonax sp.	b	X	
Vermilion Flycatcher	b		
Black Phoebe	b	X	
Say's Phoebe	b	X	
Western Wood Pewee	b		
Family Hirundinidae			
Rough-winged Swallow			X
Barn Swallow	b		
Cliff Swallow	b		
Family Corvidae			
Common Raven	X	X	

Family Paridae			
Black-crested Titmouse	b	X	
Verdin	b	X	
Family Troglodytidae			
House Wren		e	X
Bewick's Wren	b	X	
Cactus Wren	b	X	
Canyon Wren	b	X	
Rock Wren	b	X	
Family Mimidae			
Mockingbird	b	X	
Curve-billed Thrasher	b	X	
Family Turdidae			
Robin		X	X
Hermit Thrush		e	X
Family Sylvidae			
Black-tailed Gnatcatcher	b		
Blue-gray Gnatcatcher			X
Ruby-crowned Kinglet		X	X
Family Bombycillidae			
Cedar Waxwing		X	X
Family Ptilogonatidae			
Phainopepla			X
Family Lanidae			
Loggerhead Shrike	b	X	
Family Vireonidae			
Bell's Vireo	b		
Gray Vireo	b		
Solitary Vireo			X
Family Parulidae			
Orange-crowned Warbler		X	X
Myrtle Warbler			X
Audubon's Warbler		X	X
MacGillivray's Warbler			X
Yellow-breasted Chat	b		
Family Ploceidae			
House Sparrow	b	X	
Family Icteridae			
Brewer's Blackbird		X	
Bullock's Oriole	b		
Orchard Oriole	b		
Scott's Oriole	b		
Brown-headed Cowbird	b	e	
Family Thruapidae			
Western Tanager			X
Summer Tanager	b		
Family Fringillidae			
Cardinal	e	e	
Pyrrhuloxia	b	X	
Blue Grosbeak	X		X
Varied Bunting	b		
Painted Bunting	b		
House Finch	b	X	
Lesser Goldfinch	X		X
Green-tailed Towhee		X	
Rufous-sided Towhee		X	
Brown Towhee	b	X	
Dark-eyed Junco		X	
Gray-headed Junco		X	
Vesper Sparrow		X	
Lark Sparrow		X	
Rufous-Crowned Sparrow	b	X	
Cassin's Sparrow	b	e	X
Black-throated Sparrow	b	X	
Clay-colored Sparrow			X
Chipping Sparrow		X	X
White-crowned Sparrow		X	e
Lincoln's Sparrow		X	X

DISCUSSION

The extensive riparian habitat found along Fresno Creek and in the canyons of the study area has allowed for a greater diversity of avifauna than that found throughout most of the Chihuahuan Desert. Yet, in spite of the abundance of water, records for ducks and wading birds for the area are few. This could be due somewhat to sampling bias, because visits to the area have been fewer during the fall months when these kinds of birds most likely would be there. It is doubtful, though, if many hydrophyllic birds pause there when the Rio Grande is so near.

Some of the most significant bird records of the area are of species considered rare or of limited distribution in Texas. These include the Mexican Duck, Zone-tailed Hawk, Golden Eagle, White-winged Dove, Ground Dove, Elf Owl, Lucifer Hummingbird, Varied Bunting, and Gray Vireo.

The Mexican Duck is listed as a rare and endangered species. It is known to nest along small creeks in the desert southwest (Ohlendorf and Patton 1971; Wauer 1973). There are segments of Chorro Canyon, Arroyo Primero, and Fresno Creek that consist of deep-pooled water surrounded by an extensive screen of rushes and sedges, creating a habitat that seems to be suitable for nesting Mexican Ducks. There is no evidence, however, that the occasional Mexican Ducks observed in the area are nesting individuals.

Zone-tailed hawks were seen at the Smith Ranch on May 15, 1973, by Rose Ann Rowlett. These rare raptors are known to nest high in Pine trees in the Davis Mountains to the north, and Wauer (1973) states that they nest among bluffs in several localities in Big Bend National Park. Water is a requisite for this bird, and it very likely nests among the bluffs in the canyons of the study area.

Golden Eagles have been seen by several observers over the area. Most eagle sightings were made during the late fall or winter months, probably of migrant birds. Nesting sites for these large birds of prey are certainly available, and the Golden Eagle probably did nest within the area at one time. Past history of sheep and goat ranching in the area historically has led to extensive harassment and extirpation of resident eagles.

White-wing Doves are common game birds of south Texas, and many hunters enjoy hunting the species there. Hunters in west Texas are just now discovering the western race of White-wings, and hunting pressure is increasing in this part of the state. The known range of White-wings in Trans-Pecos Texas follows the Rio Grande and up to 50 miles inward from the river. Most White-wing hunting in Trans-Pecos Texas occurs within a few miles of the Rio Grande.

Biologists have worked extensively with the White-wing in south Texas, analyzing every detail of its life history and ecological requirements. Yet very little is known about this larger member of the pigeon family in Trans-Pecos Texas. Generally, White-wings in west Texas have been assigned to the western race, *Zenaida asiatica mearnsi,* while the common White-wing of south Texas is referred to as an eastern race, *Z. a. asiatica.* The *mearnsi* race differs from the *asiatica* in being smaller bodied but with longer wings. Cottam and Trefethen (1968) suggested that at least three separate subspecies might occur in far west Texas. Wauer (1973) indicated that White-wings in the nearby Chisos Mountains do not migrate as White-wings do elsewhere. The White-wing is a common bird of the Fresno Canyon area and successfully nests there, making this an important study site in learning more of the biology of western White-wings.

Another interesting bird making its home in the Fresno Canyon area is the Elf Owl. These tiniest of owls were heard constantly at night during our stay at the Smith Ranch June 11-18, 1975. Most calls were heard coming from the cottonwood groves immediately behind the middle building and from the spring-fed canyon to the west of the building complex. The little owls were often seen by flashlight sitting in the dead cottonwood branches and the tall mesquites around the old Smith house. One bird was seen on several occasions sitting on the rafters over the remains of the Smith house porch. At least six different owls could be accounted for at one time by a combination of visual and aural perception. Barlow and Johnson (1967) summarized the status of the elf owl in Texas.

Black-chinned Hummingbirds are common summer residents of the area, but the rare Lucifer Hummingbird has also been reported. Lucifer hummers are rather common nesters in Big Bend National Park (Wauer 1973), and I would expect the species to nest in Fresno Canyon. The Broad-tailed Hummingbird nests in the higher mountains of Trans-Pecos Texas. The presence of this hummer in the Fresno Canyon area could represent nesting in the area but probably represents post-nesting wandering. Rufous Hummingbirds are common migrants throughout the mountainous Trans-Pecos, sometimes becoming the most common hummer in some localities by mid-August.

Other species of hummingbirds probably occur in the area, and an established feeder could attract them into the open to be observed. The Broad-billed, Allen's, Anna's, and Calliope hummingbirds are all rare Texas birds but likely visitors to the area.

Another Chihuahuan Desert speciality found nesting within the study area is the Varied Bunting. These beautiful little birds are not common but can occasionally be seen among the thick brush lining the arroyos and stream beds.

Rowlett's sighting of Gray Vireos is significant. This small, plain vireo is a rare nester in most of west Texas but is a common summer resident of oak-covered slopes in Big Bend National Park. Rowlett found the birds evidently breeding within the study area. Winter records for this bird in Texas are rare (Barlow and Wauer 1971). Barlow has studied this species for eight years in Big Bend National Park and would like to assess the status of the species in Fresno Canyon.

Perhaps just a bit should be said about some of the more common birds of the area. Summer Tanagers, Bullock's Orioles, Mocking Birds, Pyrrhuloxias, Cliff Swallows, Ash-throated Flycatchers, Curve-billed Thrashers, and Brown-headed Cowbirds are probably the most conspicuous components of the early summer avifauna. The array of colors displayed by the birds and readily seen by a visitor to the area immediately impresses one with the presence of birds.

Constantly heard is the confusing question-like call of Bell's Vireo, yet the bird is seldom seen without a difficult search. The cascading song of the Canyon Wren is as characteristic of the wilderness experience here as any bird song heard, especially when in the narrow canyons.

In early spring one may be aware of many very small bird-like wraiths flitting about in the dense shrubbery. Patience and a good pair of binoculars will reveal an assortment of Ruby-crowned Kinglets, Black-tailed Gnatcatchers, and Verdins pretending to be unusually busy. Late afternoons and dusk will find the sky filled with Lesser Nighthawks, and, with a little luck, one might be privileged to hear their eerie purring chatter as they swoop low over the creek bed.

The Smith Ranch is the best place to see and hear the greatest variety of birds with little effort. Chorro Canyon, Arroyo Segundo, and the tree-lined area just below the old Madrid house are also good "birding" areas. Although the list of birds from the Fresno Canyon area is lengthy, and observations have been made through every season, the list will continue to grow as additional observations are made, especially during times of migration.

MAMMALS OF THE FRESNO CANYON AREA

CLASS MAMMALIA

Order Chiroptera
- Family Mormoopidae ..... *Mormoops megalophylla*—Leaf-chinned Bat
- Family Vespertilionidae ..... *Pipistrellus hesperus*—Canyon Bat
  - *Plecotus townsendi*—Lump-nosed Bat
  - *Antrozous pallidus*—Paliid Bat
  - *Eptesicus fuscus*—Big Brown Bat
  - *Myotis yumanensis*——Yuma Bat
  - *Myotis velifer*—Cave Bat
  - *Myotis californicus*—California Bat
- Family Molossidae ..... *Tadirida brasiliensis*—Guano Bat
  - *T. molossa*—Big Freetail Bat
  - *Eumops perotis*—Western Mastiff Bat

Order Lagomorpha
- Family Leporidae ..... *Lepus californicus*—Jackrabbit
  - *Sylvilagus audubonni*—Desert Cottontail

Order Rodentia
- Family Sciuridae ..... *Spermophilus spilosoma*—Spotted Ground Squirrel
  - *S. variegatus*—Rock Squirrel
  - *Ammospermophilus interpres*—Texas Antelope Ground Squirrel
- Family Geomyidae ..... *Thomomys bottae*—Valley Pocket Gopher
- Family Heteromyidae ..... *Perognathus nelsoni*—Spiny Pocket Mouse
  - *P. penicillatus*—Desert Pocket Mouse
  - *P. merriami*—Merriam's Pocket Mouse
  - *Dipodomys merriami*—Merriam's Kangaroo Rat
- Family Cricetidae ..... *Peromyscus eremicus*—Cactus Mouse
  - *P. pectoralis*—Encinal Mouse
  - *P. leucopus*—White-footed Mouse
  - *Onychomys torridus*—Scorpion Mouse
  - *Neotoma albigula*—White-throated Woodrat
- Family Muridae ..... *Mus musculus*—House Mouse
- Family Erethizontidae ..... *Erethizon dorsatum*—Porcupine

Order Carnivora
- Family Canidae ..... *Canis latrans*—Coyote
  - *Urocyon cinereoargenteus*—Gray Fox
  - *Vulpes macrotis*—Kit Fox
- Family Ursidae ..... *Ursus americanus*—Black Bear
- Family Procyonidae ..... *Procyon lotor*—Raccoon
  - *Bassariscus astutus*—Ringtail Cat
- Family Felidae ..... *Felis concolor*—Mountain Lion
  - *Lynx rufus*—Bobcat
- Family Mustelidae ..... *Mephitis mephitis*—Striped Skunk
  - *Spilogale gracilis*—Western Spotted Skunk
  - *Conepatus mesoleucus*—Hog-nosed Skunk
  - *Taxidea taxus*—Badger

Order Artiodactyla	
Family Tayassuidae	*Tayassu tajacu*—Javelina
Family Cervidae	*Odocoileus hemionus*—Mule Deer
Family Bovidae	**Ammotragus lervia*—Auodad

* Introduced exotic species.

DISCUSSION

Generally, the mammalian fauna of the Fresno Canyon area is composed of cosmopolitan Chihuahuan species that would be expected there. It is the few exceptions that make the area unique for mammalogists. The chiropteran fauna of the area best reflects the Mexican affinities of the fauna as a whole. Some of the rarest species of bats recorded for the United States have been documented from the study area, and at least three additional rare species are to be expected. Nearly all these bats are fairly common species much further south in Mexico, with the study area just coming within their northernmost distributional range.

The rare Leaf-chinned Bat was netted over Fresno Creek just behind the Smith Ranch building complex. Two individuals were retained for voucher specimens (SRSU 1580-81) and all others released. One of the specimens (SRSU 1580) was a pregnant female (Fig. 1) with an embryo measuring 45 mm rump-crown. The pellage of this female was a distinctive reddish-brown, while that of the other, a nonpregnant female (SRSU 1581), was almost a chocolate brown.

Western Mastiff Bats and Big Free-tailed Bats were netted over large pools of water in Arroyo Segundo but were not netted at any other sites. The Western Mastiff Bat (Fig. 2) is known from less than a half-dozen localities in Texas. The second record of this rare mollosid bat in Texas was from the nearby Fresno Mine (Eads et al. 1957). Roosts of this largest bat found in the United States have been reported only from Big Bend National Park (Constantine 1961) and Capote Canyon (Ohlendorf 1972).

Records for the Big Free-tailed Bat in Texas are also sketchy, mostly consisting of single captures. However, Easterla (1972) captured many specimens in Big Bend National Park, banding 284 at two sites. He also located day-roosting sites high on cliffs in Fern Canyon, a Mexican tributary to Santa Elena Canyon. Borrell's (1939) earlier report of a colony in Pine Canyon of the Chisos Mountains was the first and only report of a colony of these rare bats in Texas until Easterla's (1973) recent report.

Western Mastiff Bats and Big Free-tailed Bats were both fairly common in Arroyo Segundo, indicating possible colonies nearby. However, mollosid bats are strong fliers and could be flying in for water from some other area, such as the Solitario.

At least three additional species of rare bats probably occur, at least seasonally, within the study area. These are the Spotted Bat (*Euderma maculatum*), the Mexican Long-tongued Bat (*Leptonycteris nivalis*), and the Pocketed Free-tail Bat (*Tadarida femorosacca*). All three of these species have been reported from Big Bend National Park (Easterla 1973).

The Spotted Bat is often described as the most beautiful of bats. It is presently known in Texas only in Big Bend National Park. Mexican Long-tongued Bats are nectar feeders and especially relish the nectar of blooming century plants. It has been taken from Big Bend Park to the east and the Chinati Mountains (Mollhagen 1973) to the west. The Pocketed Free-tail Bat was unknown to Texas until 1967 (Easterla 1968), but recent work by Easterla (1973) showed the species ranked 11th of 18 species in frequency of occurrence at capture sites in Big Bend National Park. The nearness of the study area to Big Bend National Park and the similarity of much of the terrain and physiography to capture sites in Big Bend are reasons enough to expect most of the species here that Easterla (1973) recorded in his thorough five-year study of bats of Big Bend National Park.

The most common bats of the area are the Guano Bat and the tiny Canyon Bat. Guano Bats, or Mexican Free-tailed Bats, are the most common bats at Carlsbad Caverns and often reach high densities in areas affording good shelter and abundant insect prey. The riparian habitat of the study area provides high numbers of insects, while the rugged landform is prolific with crevices and small caves for roosting sites. The presence of mine shafts in the area and nearby also has provided ideal habitat for this and other species of bats.

The Canyon Bat is probably the smallest bat of the study area, rivaled in size only by the Yuma Bat. The Canyon Bat is often seen in late afternoon as long as 30 minutes before sundown, foraging low over the trees along the creeks. Early risers, will often see it apparently still flying after sunrise. Actually, this tiny bat spends much of the night in a roost, coming forth

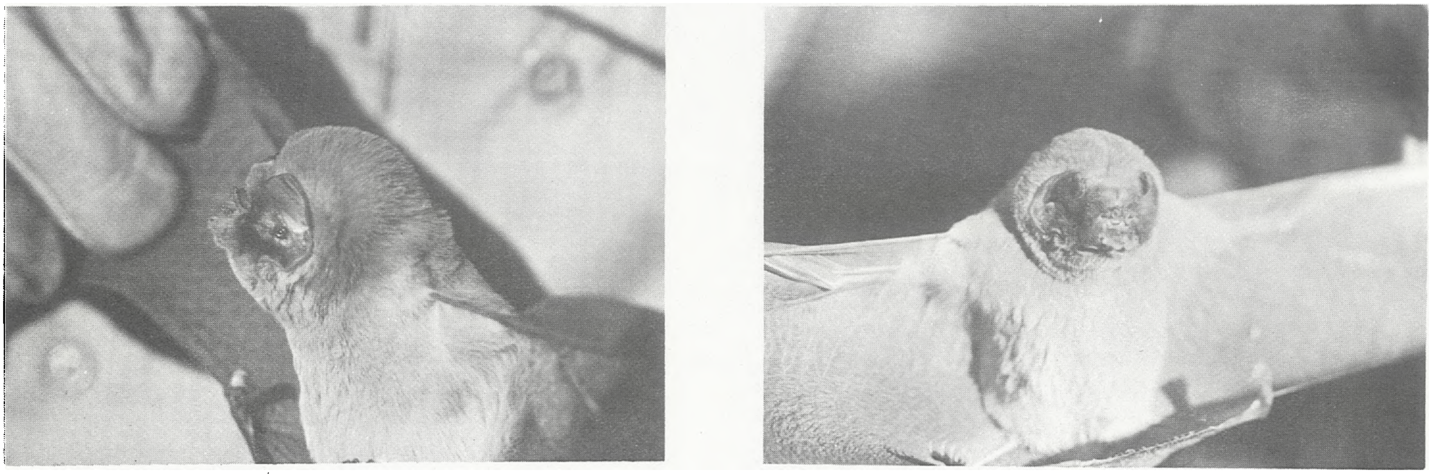

FIGURE 1

Female Leaf-chinned Bat (SRSU 150) from the Smith Ranch, Fresno Canyon.
A rare species of bat.

FIGURE 2

A rare Mastiff Bat from Arroyo Segundo, Fresno Canyon area.

to forage well before and after other bats become active.

The most visual rodents are the large Rock Squirrels and the smaller Antelope Ground Squirrel. Both of these squirrels are often seen in roughland habitats, with the Rock Squirrel occupying the rocky rims and the flashy little Antelope Ground Squirrel preferring the canyon bottoms, arroyos, and hill slopes.

The most common rodents are seldom seen, at least during the day. Nocturnal species such as the Merriam's Kangaroo Rat, the three species of pocket mice, and the White-throated Woodrat may be seen in the roads by car light on hot summer nights. The secretive Encinal Mouse is the most common rodent over the entire area, according to trapping records. This was the only species of *Peromyscus* captured in Chorro Canyon. The absence of the Brush Mouse (*Peromyscus boyli*) from the study area is a mystery. The Brush Mouse was the only *Peromyscus* captured in nearby Colorado Canyon. These two species of *Peromyscus* appear to competitively exclude each other in this area but do not do so farther to the north where the two species may be taken together.

Porcupines are occasionally encountered here as elsewhere throughout the Trans-Pecos Region. Predation by large carnivores, particularly Mountain Lions, probably keeps the porcupine population well controlled. Little evidence of damage to trees by porcupines was noted within the study area.

The nearness of the Mexican border to the study area has allowed the presence of at least two species of mammals that would not be found here otherwise. Black Bears have been found here in the past, although there are no recent records. Bears are known to wander occasionally into rugged areas of the Big Bend country from Mexico but usually are killed quickly when discovered. Mountain Lions are now rather common in this area of the Big Bend but only because a refugium existed in Mexico during the years of heavy persecution by sheep and goat ranchers of the area. The shift from sheep and goat ranching to strictly cattle operations removed much of the pressure on Mountain Lions, but there are still some efforts made to control the big cats because of their predation on Mule Deer and horses. A recent study of Mountain Lions in Trans-Pecos Texas (McBride 1976) revealed that Mountain Lions are effective predators of porcupines.

Hoofed mammals are represented in the area by two native species and at least one introduced exotic. The Mule Deer is the most important species from the point-of-view of economics. At present the Diamond A Ranch allows over 200 hunters to participate in the annual 16-day Mule Deer hunt. Exact numbers of deer actually harvested from the ranch as a whole are not presently known. It would be more difficult to get an accurate count of deer taken from the study area only. Because of the high value placed upon the deer herd, the ranch maintains a program of Mountain Lion control.

Javelinas are common in the area, and are often shot by hunters, but no information is available as to the number of Javelinas killed on the Diamond A Ranch. Skeletal remains, including nine skulls of Javelinas of various ages, were found in an area just below the rim on the east facing slope of Chorro Canyon. Evidence indicated these animals had been killed by a hunter some years previously.

Aoudad were introduced to the Big Bend Ranch by the Fowlkes Brothers in the late 1950s. By 1965 the Aoudad was hunted in limited numbers on the ranch. Ralph Hager, foreman of the Diamond A, said there are few if any left. None have been sighted within the past several years. Mr. Hagar attributed the demise of the Aoudad to Mountain Lions. This introduced exotic probably no longer occurs anywhere on the Diamond A Ranch. Certainly the rugged topography of the study area would be a logical last stronghold of the species, but I am not even sure the Aoudad ranged onto this particular part of the Ranch. Other exotics have been introduced at times, all without success.

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BUTTERFLIES OF THE SOLITARIO – FRESNO CREEK – BOFECILLOS MOUNTAINS REGION WESTERN BIG BEND (PRESIDIO AND BREWSTER COUNTIES) TEXAS

Christopher J. Durden

Forty-seven species of butterflies in the western Big Bend region were recorded during collecting visits in May 1973, October 1974, and June 1975. Although this list is perhaps less than one-half of the potential, it is possible to draw some conclusions regarding the faunal affinities of the area.

There are a few taxa of restricted range. Two are restricted to the immediate Big Bend Region of West Texas (including the Davis Mountains): *Megisto rubricata smithorum* and *Thessalia chinatiensis.* Two are restricted to a narrow band, and extension of the Sierra Madre Oriental of Mexico: *Strymon* new species and *Celotes limpia.* One occurs throughout the Rio Grande basin below Albuquerque and westward through the Lordsburg gap over surfaces drained by the ancestral Rio Mimbres (R. C. Belcher 1975:44) in mid-Tertiary time: *Dymasia dymas.* One is a western disjunct of a Tamaulipan shrubland species: *Thessalia theona bollii.* Four are Sonoran desert species either disjunct or at the eastern edge of their ranges (which pass through the Lordsburg gap): *Chlosyne lacinia crocale, Asterocampa leila, Asterocampa subpallida,* and *Systasea zampa.*

Four species are widely distributed in both Sonoran and Chihuahuan deserts: *Papilio rudkini clarki, Calephelis nemesis, Cogia hippalus,* and *Atrytonopsis ovinia edwardsi.* Two have a Kansan Province (short grass prairie) distribution and are at the southern end of their range: *Phyciodes picta* and *Amblyscirtes oslari.* One eastern deciduous forest species is disjunct here and in Durango: *Polygonia interrogationis.* One is eastern Neotropical, extending into the eastern Great Plains: *Agraulis vanillae incarnata.*

Ten species have broad ranges on either side of the continental divide but do not extend south of Northern Mexico: *Papilio polyxenes curvifascia, Eurema mexicana, Thessalia fulvia, Limenitis bredowii eulalia, Phyciodes vesta, Leptotes marina, Strymon melinus franki, Atlides halesus corcorani, Icaricia acmon texanus, Hesperia pahaska williamsi.* Five species have broad ranges on both sides of the continental divide, mostly in Mexico: *Phoebis sennae marcellina, Kricogonia lyside, Danaus gilippus strigosus, Libytheana carinenta mexicana,* and *Copaeodes aurantiaca.*

Six species have very broad temperate ranges: *Pieris protodice, Colias eurytheme, Danaus plexippus, Euptoieta claudia, Hemiargus isola alce,* and *Pyrgus communis.* Six species have very broad subtropical ranges: *Battus philenor, Nathalis iole, Eurema nicippe, Zerene cesonia, Brephidium exilis,* and *Erynnis funeralis.* Two species range throughout North America: *Vanessa virginiensis* and *Vanessa cardui.*

The chief surprises are the lack of uniquely Chihuahuan Desert species. Species endemic to the Big Bend will probably be found south of the Rio Grande in the isolated ranges of western Coahuila and eastern Chihuahua. Endemic species of the northern Sierra Madre Oriental occur in arid habitats and should be assigned to the Chihuahuan Desert fauna (they are not likely however to be found in Chihuahua). Disjuncts from both Tamaulipan and Sonoran provinces suggest that the Rio Grande has been an important route of dispersal. The several species that leak through the Lordsburg Gap from the Sonoran desert indicate that this mid-Tertiary segment of the Rio Grande drainage, the ancestral Mimbres-upper Gila River of mid-Miocene to mid-Pliocene time (Belcher 1975:38), has been and continues to be an important passage for extension of ranges of both eastern and western desert species.

Locality Register

All voucher specimens are numbered as follows: First two digits are last two of the year, next three digits are day of the year, followed by a punctuating letter designating site collected during the day, terminated by unique specimen number. Number is prefixed by collector's name in citation.

Solitario Localities

Brewster County

Lefthand Shutup (103.75-6°W, 29.47°N): 73141J, 75162B.

Tres Papalotes (103.77°W, 29.45°N): 73141H, 75159A (part).

Summit and ridge south of Tres Papalotes (103.77°W, 29.44°N): 75159A (part).

SUMMARY OF OCCURRENCE OF BUTTERFLIES IN THE SOLITARIO (S), FRESNO CREEK (F), AND BOFECILLOS MOUNTAINS (B) OF WESTERN BIG BEND, TEXAS

1	*Battus philenor*	S	F	
2	*Papilio polyxenes curvifascia*	S	F	
3	*Papilio rudkini clarki*	S	F	
4	*Pieris protodice*	S		
5	*Nathalis iole*		F	
6	*Colias eurytheme*	S		
7	*Zerene cesonia*		F	
8	*Eurema mexicana*	S		
9	*Eurema nicippe*	S	F	B
10	*Phoebis sennae marcellina*		F	
11	*Kricogonia lyside*		F	
12	*Danaus gilippus strigosa*	S	F	B
13	*Danaus plexippus*		F	
14	*Megisto rubricata smithorum*	S	F	
15	*Agraulis vanillae incarnata*		F	
16	*Euptoieta claudia*		F	
17	*Polygonia interrogationis*		F	
18	*Vanessa virginiensis*	S		
19	*Vanessa cardui*	S		
20	*Chlosyne lacinia crocale*	S		
21	*Thessalia chinatiensis*	S		
22	*Thessalia theona bollii*	S		
23	*Thessalia fulvia*	S		
24	*Dymasia dymas*		F	
25	*Phyciodes vesta*	S	F	
26	*Phyciodes picta*		F	
27	*Limenitis bredowii eulalia*		F	
28	*Asterocampa leila*	S	F	B
29	*Asterocampa subpallida*			B
30	*Libytheana carinenta mexicana*		F	
31	*Calephelis nemesis*		F	B
32	*Atlides halesus corcorani*		F	
33	*Strymon melinus franki*	S	F	
34	*Strymon* new species	S	F	
35	*Brephidium exilis*	S		
36	*Hemiargus isola alce*	S	F	B
37	*Leptotes marina*	S	F	B
38	*Icaricia acmon texanus*	S		B
39	*Cogia hippalus*			B
40	*Systasea zampa*			B
41	*Erynnis funeralis*	S	F	
42	*Celotes limpia*	S		B
43	*Pyrgus communis*	S		B
44	*Copaeodes aurantiaca*	S	F	
45	*Herperia pahaska williamsi*		F	
46	*Amblyscirtes oslari*	S		
47	*Atrytonopsis ovinia edwardsi*	S	F	

Presidio County

Fresno Peak (103.83°W, 29.42°N): 75162A (part).

Chert ridge and gulch south of Middle Tank (103.81°W, 29.44°N); 75162A (part).

Middle Tank (103.81°W, 29.44°N): 75161C (part).

Grays Ridge Gulch (103.81°W, 29.44°N): 75161C (part), 73140E.

Grays Ridge (103.80°W, 29.43°N): 73140D.

Lower Shutup (103.80°W, 29.41°N): 73140A.

Righthand Shutup to Solitario Peak (103.84-5°W, 29.45-6°N):73136C.

Rim of Solitario and limestone summit west of Solitario Peak (103.84°W, 29.46°N): 73136A.

Southwest chimney of Solitario Peak (103.84°W, 29.46°N): 73136B.

Gulch and limestone summit north of Solitario Peak (103.84°W, 29.46°N): 75160A.

East slope of Solitario Peak (103.83°W, 29.46°N): 73140C, 75160A (part).

South slope of Solitario Peak (103.83°W, 29.46°N): 75161A.

Localities in the Western Drainage of Fresno Creek

Presidio County

Log Spring Draw (103.87°W, 29.45°N): 73137B.

Slopes above Log Spring Draw (103.87°W, 29.45°N): 73137A.

Seep Springs Draw (103.86°W, 29.44°N): 73137C.

Upper and Lower Seep Springs (103.87°W, 29.44°N): 73138A.

Summit and slopes west of Seep Springs (103.88°W, 29.45°N): 73137B.

Smith Ranch (103.86°W, 29.39°N): 73135A (part).

Smith Spring Draw (103.87°W, 29.39°N): 73135A (part).

Rancho Madrid (103.87°W, 29.37°N): 73138D, 74293B.

Chorro Canyon below Madrid Falls (103.88°W, 29.37°N): 73138C, 74291A, 74293A.

Chorro Canyon above Madrid Falls (103.88°W, 29.38°N): 73138F, 74292B.

Localities in the Bofecillos Mountains

Presidio County

Bofecillos Canyon, springs below pictographs (104.10°W, 29.49°N): 73142A.

Lower Tapado Canyon, springs above main fork (104.08°W, 29.38°N): 73143A.

All voucher specimens are curated in the Ecological and Systematic Survey of Texas Arthropods (ESSTA)

Collection of Texas Memorial Museum, 2400 Trinity Street, Austin, Texas 78705, and are available for study by qualified investigators.

Family PAPILIONIDAE

Battus philenor Linnaeus, 1771. 73138D1 Rancho Madrid, 75162A1 Fresno Peak.

This black and blue, glossy, orange-spotted swallowtail is conspicuous throughout the area and may be seen on warm days almost all year. It was present in hilltopping assemblages at Seep Springs summit and on Fresno Peak, and was seen flying along washes west of Fresno Creek and in the Shutups of the Solitario. Adults frequently feed at the blooms of desert willow *Chilopsis linearis,* and the larvae feed exclusively on species of *Aristolochia.*

Papilio polyxenes curvifascia Skinner, 1902. 73137B sight Seep Springs summit, 75159A5-9 Tres Papalotes summit, 75160A9 summit N of Solitario Peak.

This yellow-spotted, black swallowtail was a frequent component of hilltopping assemblages on the summit north of Chorro Canyon, summit west of Seep Springs, rim summits west of Solitario Peak, Solitario Peak, and Gray's Ridge. It is distinguished from its sibling *P. rudkini* by the odor (resembling cheap perfume) of the androconial scales of the male forewing, the irregularly aligned and rough-edged spots of the post-median yellow band, the coarse or fluffy appearance of the wing scales, and the black cast of the ventral proximal dark area of the wings. Where *P. polyxenes* occurs in arid regions, in potential sympatry with *P. rudkini,* it is represented by the subspecies *curvifascia* and individuals resembling the eastern subspecies, *asterius* Stoll, are uncommon. Larvae of *P. polyxenes* feed on Umbelliferae and the occasional reports of Rutaceae may refer to individuals of the following species.

Papilio rudkini clarki Chermock & Chermock, 1937. 73140D2 Gray's Ridge, 73137B1 Seep Springs summit, 75162A2 Fresno Peak.

This very close sibling species is distinguished from *P. polyxenes* by the odor (citrus) of the androconia or scent scales of the male forewing, the straighter alignment of the more evenly bordered post-median spotband, the smoother appearance of the scales, and the gray cast of the ventral proximal dark area of the wings. *P. r. clarki* is the dark form of the species found in areas where *P. rudkini* and *P. polyxenes* are sympatric, from eastern California through eastern Arizona to southern Colorado, eastern New Mexico, and the Edwards Plateau (Travis County) of Texas. Its range southward in the Chihuahuan Desert region has not been documented. It is found in arid habitats; rock summits in the west; gravel-covered river terraces and talus in the east. *P. rudkini* larvae feed on Rutaceae, particularly species of *Thamnosma. P. r. clarki* appears to grade into the Central American *P. americus stabilis* Rothschild and Jordan in South Texas (Hays and Bexar Counties). When details of its biology are worked out *clarki* (and other races of *rudkini* and *coloro* Wright) will probably be recognized as subspecies of *P. americus* Kollar as was predicted by Edwards in 1877.

Family PIERIDAE

Pieris protodice Boisduval & Leconte, 1829. 73136A1-2 summit west of Solitario Peak, 75159A11 summit south of Tres Papalotes, 75161C21-23 Middle Tank.

This common white desert butterfly is a frequent component of hilltopping assemblages. It is also encountered flying along washes where its larval foodplants, various cruciferous weeds, occur. It was commonly seen visiting the sunflowers on the graded area of Middle Tank.

Nathalis iole Boisduval 1836. 73138D sight Rancho Madrid.

This widespread species of desert and plains occurs in weedy areas along washes as well as on heavily grazed pasture where the foodplants are found. These include species of *Dysodia, Helenium, Stellaria, Bidens, Thelosperma,* and *Palafoxia.*

Colias eurytheme Boisduval, 1852. 75161C24 Middle Tank.

This temperate meadow species also occurs abundantly in desert areas along gulches where herbaceous legumes, the larval foodplants, grow. Adults habitually fly along gravel stream beds and are less frequently observed crossing open country. They are preadapted to fly along road shoulders, an artificial habitat also occupied by the larval foodplants. Hence the species has extended its range eastward in historic times. The species breeds year round at this latitude and numbers are highest in spring and fall.

Zerene cesonia Stoll, 1790. 73138D sight Rancho Madrid.

This species is an occasional hilltopper and is seen frequently flying across desert scrub in the Solitario. Adults are avid flower visitors, feeding at desert willow *Chilopsis linearis* and wild china *Sapindus saponaria.* The larvae feed on various herbaceous legumes.

Eurema mexicana Boisduval, 1836. 75161C25-26 Middle Tank.

This species ranges from tropical forest habitats in Central America to montane woodland sites in the Rocky Mountains. In the latter area the larval foodplant is *Robinia neomexicana.* In this area it may use *Cassia lindheimeriana* or one of the *Acacia* species.

Eurema nicippe Cramer, 1780. 73138D3 Rancho Madrid, 73141H1 Tres Papalotes, 73143A1 lower Tapado Canyon, 74291A7 lower Chorro Canyon, 75161C20 Middle Tank.

At times this is one of the commonest butterflies of the area. A small orange butterfly, it is seen frequently along washes and the lower valley flats where the principal foodplant senna, *Cassia linhdeimeriana,* grows. Adults may be found in warm weather at any time of year.

Phoebis sennae marcellina Cramer, 1777. 73138D2 Rancho Madrid, 74292B3 upper Chorro Canyon, 74293B3-4 Rancho Madrid.

This large, yellow-sulfur butterfly (which has both orange and white forms of the female) is seen infrequently along dry washes in all areas. Old adults have a strong odor of rancid butter. The larvae feed on various species of senna, *Cassia* spp. in a tent formed from a folded leaf, tied with silk.

Kricogonia lyside var. *terissa* Lucas, 1852. 73138D4 Rancho Madrid.

This species of the Chihuahuan Desert and Tamaulipan shrubland feeds, as larva, on guyacan, *Porlieria angustifolia.* A female was observed to oviposit on this shrub at upper Seep Spring. The species occurs as several genetically determined varieties and phenotypic forms of quite different appearance, the ecological significance of which is not yet understood. Under epidemic conditions, all named forms and varieties have been taken together. Following certain climatic events this species migrates in flocks of millions of individuals, often in the company of the snout butterfly, *Libytheana bachmanii.* Adults of *K. lyside,* when not in migration, tend to be crepuscular, or most active at dusk, when they gather in bushes about seeps and springs. Occasionally they congregate at the flowers of wild china, *Sapindus saponaria.*

Family NYMPHALIDAE

Danaus gilippus strigosa Bates, 1864. 73138D sight Rancho Madrid, 73135A sight Smith Ranch, 73137B sight Log Spring Draw, 73136C sight Righthand Shutup, 73140A sight Lower Shutup, 73141J sight Lefthand Shutup, 73142A3 Bofecillos Canyon, 74293B2 Rancho Madrid, 75161C5 Middle Tank.

This small, dull brown to tan monarch is frequent along washes where the foodplants (*Asclepias* spp.) of the larvae grow.

Danaus plexippus Linnaeus, 1758. 73138D9 Rancho Madrid, 74291A1 upper Chorro Canyon, 74293B1 Rancho Madrid.

A larger number of monarchs were seen in the area than was expected. In both May and October, most were in sustained flight along dry washes, but some were engaged in roosting activity in trees around Smith Spring and Seep Spring. No monarchs were seen in June, and it is unlikely that they breed in the area.

Megisto rubricata smithorum Wind, 1946. 73140C1 east slope Solitario Peak, 73138C1 lower Chorro Canyon, 73137B2-3 slopes of Seep Springs summit, 73136C1 dry wash west of Solitario Peak, 73136B1-6 SW chimney of Solitario Peak, 73135A1-4 Smith Spring draw, 74292B4 upper Chorro Canyon, 75159A2 ridge south of Tres Papalotes, 75160A1,7 east slope Solitario Peak, 75161C1 Gray's Ridge Gulch, 75162A3 chert ridge south of Middle Tank.

The subspecies *smithorum* is found in oak and juniper woodland habitats in the Davis and Chisos Mountains. Subspecies *rubricata* is found in oak and juniper woodland habitats of the Guadalupe Mountains, Wichita Mountains (Oklahoma), and Edwards Plateau. Subspecies *cheneyorum* occurs in oak and juniper woodland of eastern Arizona and southern New Mexico. An underscribed subspecies occurs in live oak woodland at the eastern edge of the Edwards Plateau and in the Serranias del Burro (Coahuila). The Solitario populations differ from but are closest to *smithorum.* They are the only nonwoodland race yet known of *M. rubricata.* Adults may be flushed from the tall tufted grasses, the probable larval foodplant, that grow on the steep upper talus slopes below chert or volcanic cliffs. It is in such situations that other woodland relicts are found, including scattered oaks. *M. rubricata* is found far beyond these oaks, however. The distribution of this species is probably relict from a time when much of the Solitario and Fresno Canyon were clothed in oak woodland.

Agraulis vanillae incarnata Riley, 1926. 73138D sight Rancho Madrid.

The gulf fritillary is usually found along well-vegetated washes where its larval foodplants, the vine *Passiflora* spp. grow.

Euptoieta claudia Cramer, 1776. 73137B sight Seep Springs summit.

This fritillary of the Great Plains and Mexican Plateau is abundant where heavy grazing has disturbed the grassland to the point that weedy plants such as *Portulaca* spp., *Sedum* spp., *Meibomia* spp., and *Plantago* spp. can act as larval foodplant. Larvae have also been found to eat many other plants, including species of *Viola, Passiflora, Menispermum,* and *Podophyllum* in other areas.

Polygonia interrogationis Fabricius, 1798. 74292B2 upper Chorro Canyon.

This widespread species of eastern North America is (except for a population in Durango), unusual west or south of the prairies and Edwards Plateau. As food, the larvae prefer species of *Celtis,* but will also eat species of *Ulmus, Humulus, Urtica,* and *Tilia.*

Vanessa virginiensis Drury, 1773. 73140A sight Lower Shutup, 75161C14 Middle Tank.

This is a common species of shrublands, where the larval foodplants are species of *Senecio, Artemisia, Anaphalis, Antennaria, Gnaphalium, Myosotis, Antirrhinum* and *Malva.* Adults may be found on warm days in winter.

Vanessa cardui Linnaeus, 1758. 73140C sight east slope Solitario Peak. 73141J sight Lefthand Shutup.

This is a common species of arid shrublands, where it utilizes as larval food species of *Malva, Althea, Borago, Cirsium, Carduus, Centaurea, Arctium, Anaphalis, Artemisia,* and *Gnaphalium.* The species is found on all continents except Australia. It breeds year round in the Sonoran, Chihuahuan, Saharan, Arabian, and Gobi deserts and emigrates annually to higher latitudes, having been taken at the northernmost point of Greenland.

Chlosyne lacinia crocale Edwards, 1874. 75159A10 summit south of Tres Papalotes, 75161C19 (near *adjutrix*) Middle Tank, 75162A5 (*crocale*), 6 (near *adjutrix*) Fresno Peak.

This butterfly is found in disturbed sites in arid regions on both sides of the continental divide. It is at the eastern edge of its range here and shows evidence of intergradation with the Tamaulipan *C. l. adjutrix.* The latter ranges northwest to the Texas Panhandle (Blackwater Draw) and eastern New Mexico. Typical *C. l. crocale* was unexpected in the Solitario. The larval foodplants include a number of species of sunflowers of several genera.

Thessalia chinatiensis Tinkham, 1944. 75161A2-3 south slope Solitario Peak, 75162A7-9 Fresno Peak.

This West Texas endemic occurs in the Chinati Mountains, at Toyahvale, and near Terlingua. In Big Bend National Park it is found at lower elevations than the related *T. thekla* Edwards, which feeds as larva on *Castilleja lanata* and *Verbena* in the Sonoran desert. *T. thekla* has not yet been found in the Solitario area, where *T. chinatiensis* is found at moderate and high elevations, and is always associated with *Castilleja* spp. On Fresno Peak *T. chinatiensis* flies with *T. fulvia.*

Thessalia theona bollii Edwards, 1877. 75159A4 summit south of Tres Papalotes.

This species of the Tamaulipan shrubland is at the western and northern extremity of its range here. In South Texas its larvae are known to eat *Leucophyllum texanum.* It was found here with *T. fulvia* on a shrubby summit.

Thessalia fulvia Edwards, 1879. 73137B4-5 Seep Springs summit, 75159A3 summit south of Tres Papalotes, 75160A3-6 summit north of Solitario Peak, 75161C17-18 slopes above Gray's Ridge Gulch, 75162A10-13 Fresno Peak.

This species is found on dry, rocky summits where the larval foodplant *Castilleja* spp. grows. The thermoregulatory and territorial habits of this species are similar to the more northern genus *Euphydryas,* to which *T. fulvia* bears a superficial resemblance.

Dymasia dymas Edwards, 1877. 74292B5-6 upper Chorro Canyon.

This species of the Chihuahuan Desert and Tamaulipan shrubland is known to feed as larva on *Siphonoglossa pilosella.* Specimens taken in upper Chorro Canyon were all of the large light form *larunda* Strecker. Individuals of the typical form were seen in lower Chorro Canyon.

Phyciodes vesta Edwards, 1869. 73138D5 Rancho Madrid, 75162A4 chert gulch south of Middle Tank.

This species of dry washes in arid country and the subtropics utilizes *Siphonoglossa pilosella* as larval foodplant.

Phyciodes picta Edwards, 1865. 73138D6 Rancho Madrid, 74293B12-15 Rancho Madrid.

This species of the southern Great Plains (there is another race in the Sonoran Desert) occurs in grassy areas around seeps and along washes where *Aster* spp., the larval foodplants, grow.

Limenitis bredowii eulalia Doubleday, 1848. 73138F sight upper Chorro Madrid.

This large, spectacular, white-banded, black butterfly with orange-spotted wing apex occurs typically in oak woodland habitats of northern Mexico, mountains of the continental divide to Colorado, and the Edwards Plateau and Trans-Pecos ranges of Texas. Elsewhere, the larvae are known to eat various species of each of the three temperate American oak subgenera. In Chorro Canyon it may utilize *Quercus oblongifolia.* In the Davis Mountains *Q. hypoleucoides* is the presumed larval foodplant.

Asterocampa leila Edwards, 1874. 73138D7-8 Rancho Madrid, 73143A2 lower Tapado Canyon, 74291A1-6 lower Chorro Canyon, 74292B1 upper Chorro Canyon, 74293B7-10 & 11 (var.) Rancho Madrid, 75162B1 Lefthand Shutup.

This species is closely associated with the low shrubby growth of *Celtis pallida,* the larval foodplant. All specimens from this area are of the typical subspecies (described from the Sonoran Desert) rather than the south and central Texas subspecies *cocles* Lintner.

Asterocampa subpallida Barnes & McDunnough, 1913. 73142A1-2 Bofecillos Canyon.

This species previously was known only from the Sonoran Desert in the Santa Rita, Baboquivari, Huachuca, and Chiricahua Mountains of Arizona. Here it is associated with an old grove of *Celtis reticulata,* the presumed larval foodplant.

Family LIBYTHEIDAE

Libytheana carinenta mexicana Michener, 1943. 73138D10 Rancho Madrid, 73137A sight Log Spring Draw, 74293A2-3 lower Chorro Canyon, 74293B5-6 Rancho Madrid.

The larvae of this species feed on various species of *Celtis* and the adults are frequently seen roosting in thorn thickets along draws. Adults are often active at temperatures well over 38°C (100°F), when other butterflies have sought shaded refuge. After certain climatic events this species undergoes epidemic reproduction and adults migrate in great clouds both north and south out of the Chihuahuan Desert. All specimens taken appear to be this species rather than the very similar *L. bachmanii larvata* Strecker, which may also occur in the area.

Family LYCAENIDAE

Calephelis nemesis Edwards, 1871. 73143A sight lower Tapado Canyon, 74293B16-17 Rancho Madrid.

This metalmark is found at seeps along washes where its foodplants, *Baccharis* spp. and *Clematis* spp., grow.

Atlides halesus corcorani Gunder, 1934. 73137B6-7 Seep Springs summit.

Three individuals were defending territories on and around a large *Yucca thompsoniana* at the top of Seep Springs summit. Larval foodplants, the mistletoe *Phoradendron* spp., are uncommon in the area.

Strymon melinus franki Field, 1938. 73141H2-3 Tres Papalotes, 74292B10 upper Chorro Canyon, 75160A8 south slope Solitario Peak, 75161C5-9 Middle Tank.

This species is found around seeps; a couple were flushed from a fig bush at Tres Papalotes. The larval foodplants are diverse, mostly *Leguminosae, Malvaceae,* and *Rosaceae,* including 46 genera and 21 families.

Strymon new species. 73140D3-4 Gray's Ridge, 75159A13-17 ridge south of Tres Papalotes, 73137B sight Log Spring Draw.

This species was found hilltopping at two locations, visiting flowers of *Acacia greggii* and defending bush-top territories. It looks superficially like *Tmolus azia* Hewitson, but it is a *Strymon* spp. related to *S. melinus* and *S. rufofusca* Hewitson. Elsewhere it is known from southern Tamaulipas (Durden 70360A), probably from Big Bend National Park (specimens not seen), and possibly from Colorado (Boulder, Chataqua Mesa). In the Solitario it is associated with *Prunus havardii* thickets.

Brephidium exilis Boisduval, 1852. 75159A12 Tres Papalotes, 75160A11 gulch north of Solitario Peak, 75161C3 Middle Tank.

This species ranges throughout the Great Basin, Mexican Plateau, and arid regions of Texas, to the mouth of the Rio Grande. Larval foodplants include many common weeds such as *Atriplex bracteosa, Chenopodium album, Salicornia ambigua,* and *Petunia parviflora.*

Hemiargus isola alce Edwards, 1871. 73136C1-3 Righthand Shutup, 73137C1 Seep Springs, 73138A1-2 Smith Spring, 73138D11 Rancho Madrid, 73141H4 Tres Papalotes, 73142A8-9 Bofecillos Canyon, 73143A4 lower Tapado Canyon, 74292B7-9 upper Chorro Canyon, 74293A5 lower Chorro Canyon.

This species is frequent throughout the area and is often abundant at seeps, where it drinks interstitial water from wet silt. Foodplants of the mesquite blue include species of *Prosopis, Acacia, Albizzia, Indigofera, Melilotis, Desmanthus,* and *Dalea.*

Leptotes marina Reakirt, 1868. 73138D12 Rancho Madrid, 73141H5-7 Tres Papalotes, 73142A4-7 Bofecillos Canyon, 73143A5-6 lower Tapado Canyon, 75159A1 Tres Papalotes, 75162B2 Lefthand Shutup.

The marine blue congregates at seeps to drink on moist earth. The larval foodplants include species of *Astragalus, Plumbago, Dolichos, Galactia, Medicago, Phaseolus,* and *Lysiloma.*

Icaricia acomon texanus Goodpasture, 1973. 73143A3 lower Tapado Canyon, 75160A2 south slope Solitario Peak, 75161C4,10 Middle Tank.

Colonies of this species are very local and scattered in arid country and are associated with the larval foodplant *Eriogonum albertianum.*

Family HESPERIIDAE

Cogia hippalus Edwards, 1882. 73142A10-11 Bofecillos Canyon.

This species of Chihuahuan and Sonoran desert distribution, was found drinking at moist earth in the shade of cottonwood trees. The larval foodplant is unknown but related species utilize *Acacia* spp. and *Mimosa* spp.

Systasea zampa Edwards, 1876. 73143A7 lower Tapado Canyon.

This species of the Sonoran and Chihuahuan deserts flies along dry washes, where some of its larval foodplants grow. These are various species of Malvaceae.

Erynnis funeralis Scudder & Burgess, 1870. 73136A3 Solitario rim west of Solitario Peak, 74293A1 lower Chorro Canyon.

This widespread species of dry, disturbed open areas is quite variable in size. The unusually large October specimen from Chorro Canyon was found, upon dissection, to be this species. Known larval foodplants are species of *Lotus, Olneya, Robinia, Vicia, Indigofera, Geoffroca, Medicago,* and *Nemophila.*

Celotes limpia Burns, 1974. 75162A14 Fresno Peak.

This streaky skipper is endemic in West Texas and Coahuila. It is sympatric with the broader ranged *C. nessus* (Sonora to Oklahoma, Arizona to lower Rio Grande Valley). Both fly together at several localities and as larvae feed on various Malvaceae. *C. limpia* has been recorded as utilizing *Abutilon malacum, A. incanum, Sphaeralcea angustifolia* var. *lobata,* and *Wissadula holosericea.* In the Davis Mountains larvae of both species have been found on the same foodplant. *C. limpia* appears to occur at higher elevations and *C. nessus* at lower elevations beyond their zone of sympatry. Other records from this area are Kendall 29-31 August 1966, 1, 4-11, 17, 29 September 1966 on Ranch Road 170 15 mi SE of Redford (gulch west of Panther Canyon), and Lennox 26 March 1966, same locality.

Pyrgus communis Grote, 1872. 73143A sight lower Tapado Canyon, 75161C13 Middle Tank.

This species is widespread in disturbed areas where the larval foodplants grow. These are species of *Abutilon, Althea, Anoda, Callirhoe, Hibiscus, Malva, Sida, Sidalcea,* and *Sphaeralcea.* The single specimen is of the typical form but in the hot season the polymorphic var. *albescens* Plotz, differing in genitalic structure, is to be expected.

Copaeodes aurantiaca Hewitson, 1868. 73137C2-3 Seep Springs Draw, 73138C2 lower Chorro Canyon, 73140E1 Gray's Ridge gulch, 74292B11-12 upper Chorro Canyon, 74293A4 lower Chorro Canyon, 75160A10 gulch north of Solitario Peak, 75161C16 Middle Tank, 75161A1 south slope Solitario Peak.

This common orange skipperling is known to feed as larva on *Cynodon dactylon* elsewhere. Here it is associated with tall grasses in the heads of gulches and around springs.

Hesperia pahaska williamsi Lindsey, 1940. 73137B8 Seep Springs summit.

This skipper is found on high grasslands of Sonora, southern Arizona, Chihuahua, and western Texas. The foodplants are grasses.

Amblyscirtes oslari Skinner, 1899. 75161C2, 11, 12 Gray's Ridge gulch.

This is a species of bluff shrubland sites in prairie regions and ranges from Arizona to Saskatchewan, North Dakota, to North Central Texas (Baylor County). It is at the limits of its known distribution here. The single colony found in the Solitario is associated with the only pocket of *Quercus mohriana* (also a species of the southern plains) relict here. The life history is unknown, but the larval foodplants of its closest relatives are grasses.

Atrytonopsis ovinia edwardsi Barnes & McDunnough, 1916. 73138D13 Rancho Madrid.

This species was seen occasionally in the more rugged gulches of the Solitario. It ranges from Arizona to Coahuila (Serranias del Burro), and in Texas is known from the Guadalupe, Davis, and Chisos mountains, ranging south into Mexico.

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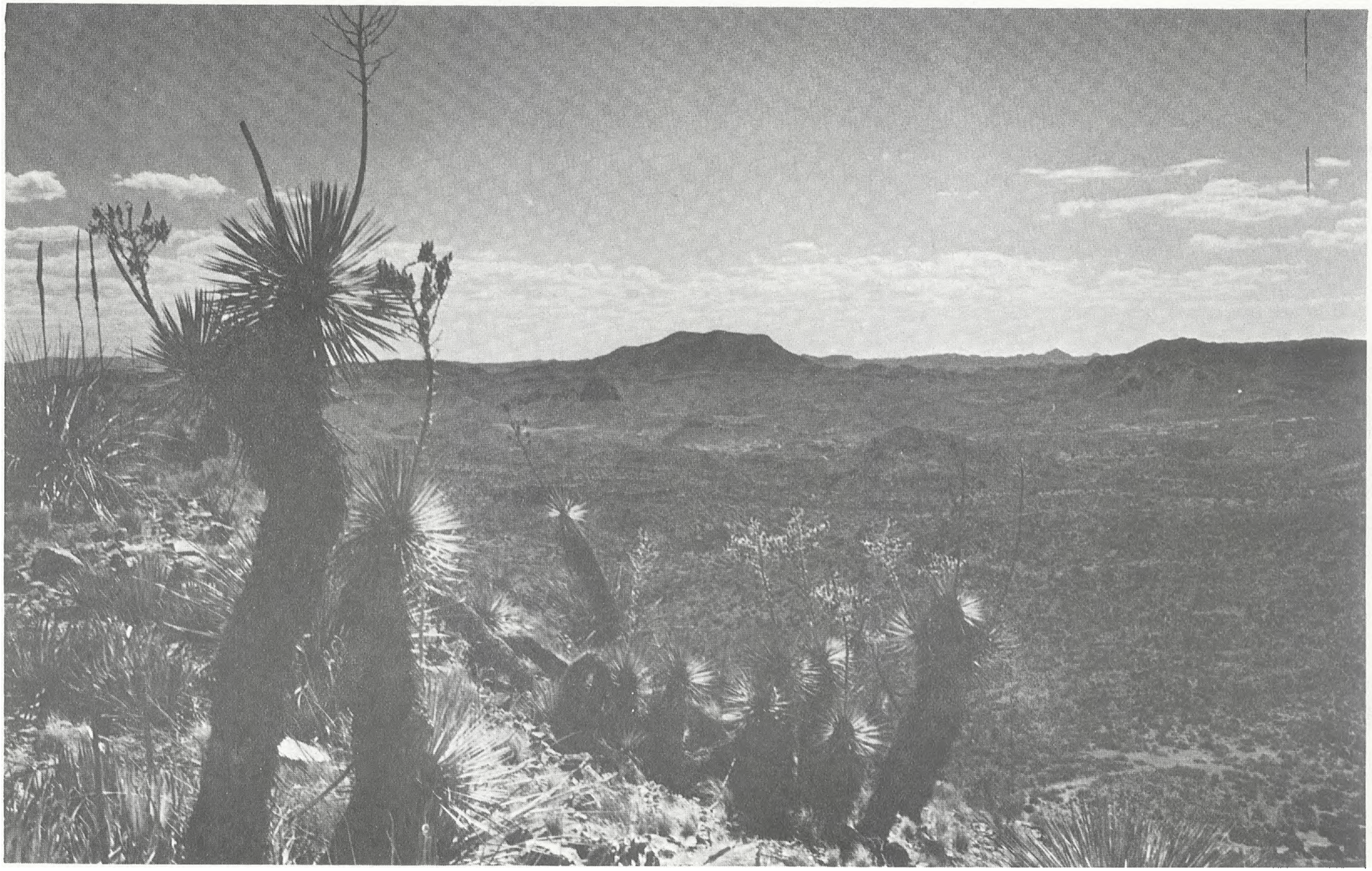

FIGURE 1

View of the interior of the Solitario looking southwest from the northern rim.
Solitario Peak is the dark igneous plug in the center interior with Fresno Peak behind on the horizon.

A PRELIMINARY ARCHEOLOGICAL RECONNAISSANCE OF UPPER FRESNO CANYON

William R. Hudson, Jr.

INTRODUCTION

Environment

Lying within the Chihuahuan Desert biotic province (Blair 1950), the Solitario and upper Fresno Canyon area is one of the most diverse and, at the same time, undisturbed archeological, biological, and geological areas of Trans-Pecos Texas (Fig. 1). The study area is characterized by an arid climate, lowland and upland environments, broad dry stream beds, boulder choked arroyos, and numerous steep-sided canyons. A low annual rainfall (30 cm) occurs mainly during the late summer months and brings with it severe flash flooding (Carr 1967:16). Natural surface water is scarce in the upper Fresno Canyon area and almost nonexistent in the Solitario, occurring only in tinajas, large bedrock depressions that catch and hold rainwater.

Generally speaking, the flora and fauna consist of arid to semiarid adaptive forms, with unusual exceptions occurring in the moist shaded canyons along the Fresno Creek drainage and its tributaries. Especially interesting are the relic plant communities that have survived in these isolated pockets, perhaps from the Pleistocene to the present, and which suggest more abundant moisture in the past. There appear to have been progressive drying and erosion at least in the last 200 years, and several local inhabitants can remember considerably more water available as little as 50 years ago. As a result of less available surface water, vegetation in the Solitario is not quite as diverse as in Fresno Canyon.

The geologic complexity of the Solitario-Fresno Canyon area provokes more than routine geologic interest. Of particular interest is the Solitario, a nearly circular domal uplift whose eroded core exposes a complexly distorted series of ancient sedimentary rocks. West of Fresno Canyon, volcanic activity and erosional forces have formed a series of lava and ash deposits, some of which contain volcanic glass that was a lithic resource for native, stone-tool using inhabitants. Rapid and recent erosion by tributaries of the Rio Grande has created a rugged and harsh environment that is formidable even to the most hardy individuals.

Erosion in these areas has created numerous rockshelters and overhangs, both at various altitudes and in numerous environmental locations. Of archeological interest, these shelters provide an excellent opportunity for animals and man to escape the harsh daytime summer temperatures and sometimes intense rainfall and provide some of the few spots of all-day shade to be found in the area. Not surprisingly, evidence of human occupation has been found at many of these shelters.

In addition, a wide variety of lithic materials suitable for tool production is found in the study area. These occur both as outcrops and as water-deposited cobbles. Geologic formations within the Solitario are primarily sandstones, shales, and chert in the northern part of the basin, and volcanic ash dominates in the southern basin. Fresno Creek is characterized by essentially volcanic formations to the west and cretaceous limestone to the east in the rim of the Solitario. This geologic diversity of Fresno Canyon, although much less than in the Solitario, presents few differences in formations suitable for rockshelters and increases the variation of lithic materials available for chipping, especially on the western side of Fresno Creek.

The Solitario and upper Fresno Canyon areas are currently used almost exclusively for ranching activities. Historically, cattle ranching has been predominant, but large numbers of sheep and goats have been grazed in the area with little attention given to range management. This activity during the last 70 years has had adverse effects on the area with overgrazing increasing the rate erosional processes on open archeological sites. Numerous rockshelters have been used as makeshift pens, disturbing the fill and talus slopes, and ranch hands and visitors to the area continually pick up artifacts of archeological interest and carry them from the sites (Ralph Hager June 1975, personal communication).

Previous Archeological Investigations

For the purpose of this report it will not be necessary to give a detailed account of all the previous archeological investigations that have been conducted in Trans-Pecos Texas as this information is available in several current manuscripts (Story and Bryant 1966; Campbell 1970; Marmaduke 1975). A brief summary of the more significant data will suffice.

Perhaps the earliest intensive work was performed by the West Texas Historical and Scientific Society of Alpine in the 1920s when over 200 sites were recorded, all within a 100-mile radius of Alpine (Fletcher 1931; Smith 1931). Victor Smith of Alpine was instrumental in this effort and contributed several publications on work he carried out in the area (Smith 1927, 1931).

Later work by Frank M. Setzler (1935) of the Smithsonian Institution also contributed to the general knowledge of the area. His investigations were conducted at a time when the Pecos Classification System for the southwestern United States was in its developing stages. The system was based primarily on information from the Four Corners area and the upper Rio Grande, and Setzler and others noticed obvious similarities between Basket Maker remains from dry rockshelters in the southwestern United States and materials found in the dry shelters in Trans-Pecos Texas. They naturally attempted to equate the two areas.

Realizing the complexity of the southwestern area, E. B. Sayles (1935) defined new terms for Trans-Pecos Texas, and, using information gathered primarily from excavated rockshelters, constructed the first chronological framework for the area.

Sayles' sequences were later modified by J. Charles Kelley who, with the help of geologists Claude Albritton and Kirk Bryan, recognized stratigraphic geological evidence for new cultural units based on a series of sites buried in the alluvial valley fill of the Alpine area (Albritton and Bryan 1939). Kelley, T. N. Campbell, and Donald J. Lehmer (1940) elaborated on this system as a result of extensive field work done in the late 1930s.

Probably the most important and useful work conducted during the early stages of Trans-Pecos archeology was the recording of numerous pictograph and petroglyph sites by A. T. Jackson (1938) and Forrest Kirkland (1967). Since these archeological resources are in an extremely fragile state and are in constant danger of being destroyed, it is fortunate that these two men provided such detailed descriptions of their findings.

Current investigations in Trans-Pecos Texas have added greatly to the body of knowledge of the area, especially the southeastern portion. Here, as a result of the construction of Amistad Reservoir on the Rio Grande in the vicinity of the Pecos River, much research has been accomplished, mainly in the early 1960s. Excavations in both open terrace sites and rockshelters have produced stratigraphic sequences of lithic tools that, together with radiocarbon dates, provide general time markers, primarily represented by projectile point types. This tool type is extremely durable and occurs on most sites in addition to exhibiting considerable morphological change through time (Story and Bryant 1966:9).

In 1967 and 1968, T. N. Campbell conducted an archeological survey of Big Bend National Park (Campbell 1970). Numerous sites were recorded, but no excavations were performed, and Campbell felt no reason to revise the classification system that he formulated with Kelley and Lehmer in 1940.

Although work has been done in many areas of Trans-Pecos Texas, numerous large areas are still unexplored from an archeological standpoint. Much of the early archeological work has been poorly documented by current research standards, and almost all of the data comes from shelter sites. Dry rockshelter situations do provide an invaluable amount of information because of excellent preservation of perishable materials, but there has been a definite lack of work conducted on other important types of sites (for example, the numerous large, open terrace sites) to determine their place in the cultural framework of the area.

Little archeological information exists on the area of the Solitario and upper Fresno Canyon, and, although the prehistory there is probably related to a trend that appears to be common throughout Trans-Pecos Texas, local variations do exist. The only information available prior to this present survey consists of 15 archeological sites located by the General Land Office in May, 1973, five of which are in the Solitario and 10 in upper Fresno Canyon. The sites represent utilization of several different habitation areas including prehistoric rockshelters, open terrace sites, and historic ranch sites. Other than this cursory survey, there has been no other work in the area.

To date, the most useful chronological study has resulted from work in the Amistad Reservoir area (Story and Bryant 1966). Although tentative, it is of tremendous value in the archeological interpretations of Trans-Pecos Texas. A simplified table of the time periods and dates, in which projectile points have been used to characterize eight time/culture periods, is shown in Table 1.

Field Procedures

Of primary concern in any archeological field research is the location of prehistoric and historic sites with emphasis on describing the characteristics of the sites and their environmental surroundings. A site here can be defined as any location occupied, utilized, or exploited by a prehistoric group. Several

TABLE I

Tentative Chronology in Amistad Reservoir from Story (1966)

Period	Estimated Date	Characteristic Projectile Point Designs
VIII	A.D.1600-?	metal arrow points
VII	A.D.1000-A.D.1600	cliffton, toyah, perdiz
VI	200B.C.-A.D.1000	ensor, frio, paisano, and figueroa
V	1000B.C.-200B.C.	montell, castroville shumla, marshall, and marcos
IV	2500B.C.-1000B.C.	langtry, val verde, and almagre
III	4000B.C.-2500B.C.	nolan and pandale
II	7000B.C.-4000B.C.	gower-like, early barbed bifurcated stem, and uvalde
I	?-7000B.C.	plainview, plainview golondrina, lerma, folsom and angostura

examples of the types of sites that might be found during a survey include: village sites, campsites, quarry sites and flaking stations where raw materials are gathered for tool production, butchering and kill sites, and plant processing sites. Usually not all types of sites are represented in any one survey, so it is important to become familiarized with any previous research conducted in the study area. The archival research should include a preliminary environmental study of the area as well as inspection of detailed topographic maps to help determine the archeological potential of any landforms.

Ideally, study areas should be surveyed according to systematic sampling procedures. However, in this case it was not feasible, a difficulty characteristic of most archeological surveys. Again, detailed topographic maps can help determine what areas should be covered, given the time limitations under which work has to be accomplished, and were invaluable aids in planning this project.

On this particular survey, two physiographic areas were being studied, the Solitario with its moderately steep-sided mountains, basin floor and choked drainages; and upper Fresno Canyon, a major stream drainage with broad alluvial and colluvial terraces, steep-walled tributaries and numerous spring locations. Our approach has been to examine intensively all major drainage and spring areas with spot-checking on other topographic locations such as mountain tops, canyon rims, flat uplands, and ridges. It is obvious from previous archeological endeavors that most prehistoric archeological sites have a close proximity to a water source, so our efforts were concentrated in these areas. Unfortunately, time precluded the coverage of much of the upland areas, but we were able to visit briefly most of the topographical and environmental settings in both areas.

The best method for locating sites proved to be traversing the land on foot. The terrain was such that vehicular travel was limited to several jeep trails through the areas. Once a site was discovered, its exact location was established on U.S.G.S. 7.5-minute topographic maps and site survey forms were completed. These include such data as site description, nearest water location, pertinent geological information, etc. In addition, detailed sketch maps were completed, along with descriptive notes, and photographs were taken of each site and of any special features or artifacts observed. All sites were given temporary identification numbers in the field and were later assigned permanent numbers using the trinomial system employed by The University of Texas at Austin. Thus, 41PS35 indicates that the site is in Texas (41), in Presidio County (PS), and is the 35th site recorded in that county. Site survey forms and photographs are filed permanently in the Office of the State Archeologist, Texas Historical Commission, and at the Texas Archeological Research Laboratory, Balcones Research Center, both in Austin, Texas.

Since the primary concern of this initial reconnaissance was site locations, no surface collections were made and no subsurface testing was performed. Although many of the sites located during the survey showed evidence of pothunting, there were areas on these sites that remain undisturbed, and many sites have not been discovered by local relic-hunters. Any collecting essentially destroys a part of the site, so, in order not to further disturb these sites, all cultural debris has been left intact. Photographs and descriptions are provided for those artifacts that show a reasonably clear indication of function, age, or possible cultural affiliations. Much can be learned from controlled surface collections and it is suggested that statistically viable controlled collecting and subsurface testing be the next step in determining the importance of the prehistoric archeological resources of these areas. Both the Solitario and Fresno Canyon are relatively isolated areas and are protected from many of the destructive forces that occur to archeological sites. However, in light of active pothunting in the area, all sites are in immediate danger of being destroyed.

In an effort to determine the availability, use, and source of lithic materials for tool production, comparative samples were taken from various sites, streambeds, and outcrops. The collections will help define the use of natural resources in the area and possibly determine any contact or foraging into other areas for desirable raw materials. Data derived from this analysis is presented in the section on site descriptions.

SITE LOCATIONS

Perhaps for as many as 10,000-12,000 years, the Solitario and upper Fresno Canyon areas have been inhabited by prehistoric peoples, and evidence of their presence is exhibited in the numerous sites located in the study area. Of the 46 sites recorded during the survey, 19 are located in the Solitario, 22 in the upper Fresno Canyon area, and five in the shutups (the constricted arroyos) that drain the interior of the Solitario. For discussion and comparative purposes, sites have been placed into these three physiographical categories, each of which exhibits sites with noticeable differences in location, size, vertical depth, and, in some instances, artifactural materials.

Sites in each of the three areas have been further categorized according to their topographic location. Those in the Solitario include gravel terrace sites, and unusual location sites. Sites in upper Fresno Canyon consist of silt terrace sites, gravel terrace sites, canyon rim sites, ridge sites, and rockshelter sites. Only rockshelter sites were observed in the shutups.

Additional site information is available in the companion volume on the Solitario (Hudson 1976) and in Appendix 1, a chart made for the purpose of conducting preliminary comparisons between sites. This chart is based entirely on surface observations.

The Shutups

There are four major drainages from the interior of the Solitario. These are characterized by steep-sided, constricted passages cut by stream action into the rim of the Solitario (Fig. 2), and, during periods of wetness, large quantities of water flow through them. Three of these drain into Fresno Canyon: the Righthand Shutup and Los Portales Shutup drain through the western rim of the Solitario, and the Lower Shutup drains through the southern rim. The fourth shutup, the Lefthand Shutup, drains northeastward and is discussed in the companion volume on the Solitario (Hudson 1976).

As mentioned, great quantities of water periodically rush through the shutups as the result of heavy rains and extremely rapid run-off. This usually occurs during late July and August. All of the shutups were traversed on foot by the survey party and all were found to be passable with little difficulty. It is interesting to note that the shutups present the easiest and most direct routes of Solitario entrance and egress, much easier than the steep-sided rim that, except for some of the northern parts, completely surrounds the Solitario.

Because of the topography of the shutups, the only locales suitable for occupation within them are rockshelters that occasionally occur in the walls overlooking the streambed. Typically, most of these shelters are small with little room for a person to move about other than in a crouching position.

Four archeological sites were located in the three shutups that drain into Fresno Canyon: Sites 41PS49 and 41PS153 in the Lower Shutup; and Sites 41PS154 and 41PS155 in the Righthand Shutup.

Sites 41PS49 and 41PS153, located in the Lower Shutup, are typical of the shelters found on these drainages. They are characterized by heavy smoke black on the ceiling, little evidence of cultural debris (one chert flake was observed at Site 41PS49), and no talus slope. Site 41PS49 (Fig. 3) is located approximately seven meters above the streambed; however, the walls of the shutup are so narrow that it is probable that the site gets washed out occasionally. Site 41PS153 is situated high on the western side approximately 70 meters above the streambed and is almost inaccessible. Smoke black and one small bedrock mortar are the only evidence of occupation.

Similar to the sites in the Lower Shutup are two others located in the Righthand Shutup. The only evidence suggesting Sites 41PS154 and 41PS155 were occupied is smoke black on the ceiling. Both shelters are small and present little in the way of protection from the elements. Both sites are located approximately five meters above the dry streambed, and the floors in each are covered with silt suggesting periodic inundation. No sites were located in the unnamed drainage south of the Righthand Shutup.

Fresno Canyon

Upper Fresno Canyon is considerably different topographically and geologically from the Solitario. It is flanked on the east by the limestone uplift of the Solitario and to the west by alternating hard and soft igneous deposits from the nearby Bofecillos Volcanic center. The bed of Fresno Creek is very wide and, although only intermittently moist over much of its course during most of the year, carries great quantities of water to the Rio Grande after intense rainfall.

In addition to Fresno Creek, two tributaries were considered in this survey, Arroyo Primero and Arroyo Segundo. Chorro Canyon, a spectacular side canyon of Arroyo Primero, is also included. These tributaries drain the uplands west of Fresno Creek. Sites in upper Fresno Canyon also differ from those in the Solitario. More diverse environmental and ecological niches exist, due primarily to the numerous springs in some areas, and, although it is difficult to determine

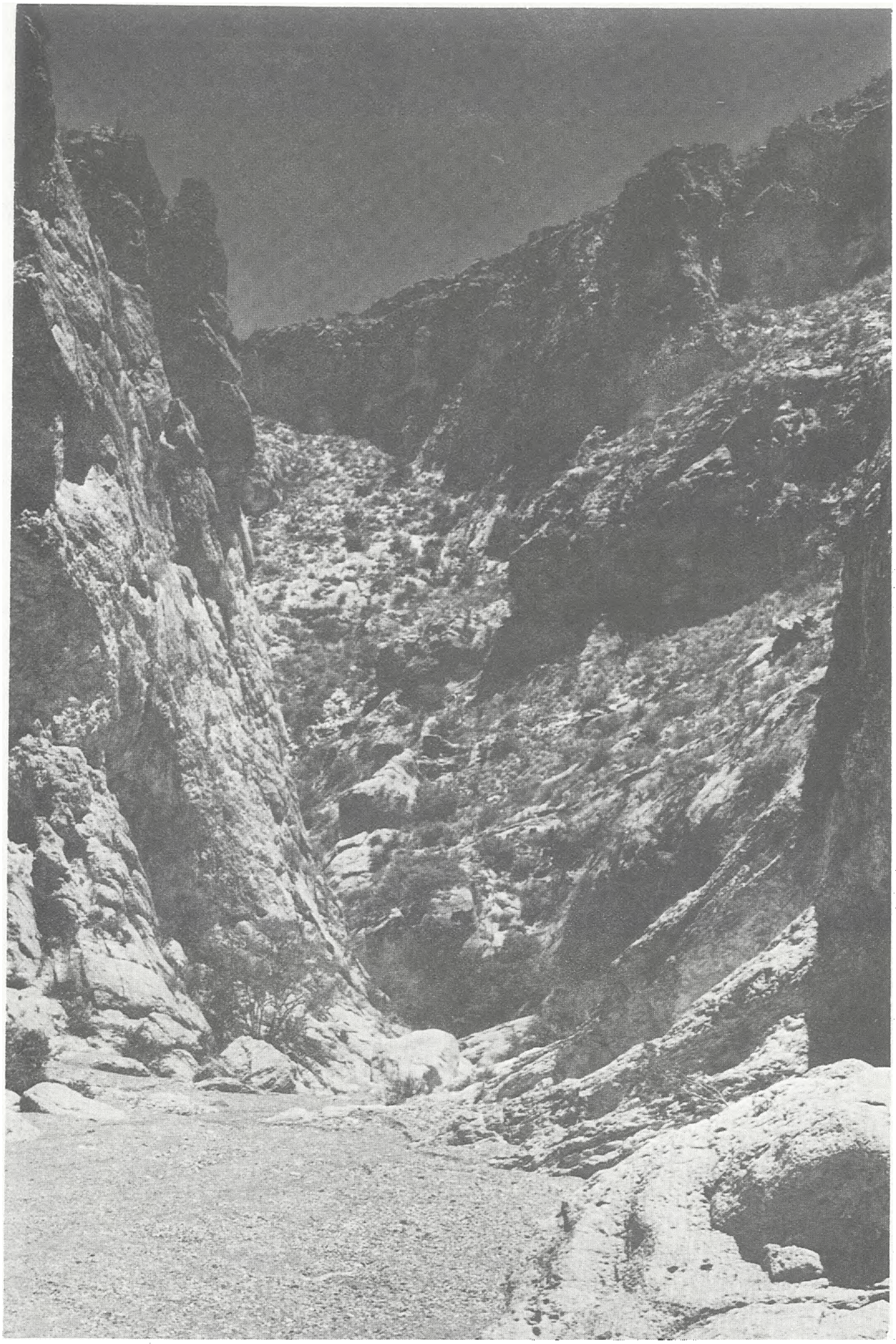

FIGURE 2

Looking east into the Lefthand Shutup.
Note steep walls of the eastern Solitario rim and the scoured stream bed.

FIGURE 3

Site 41PS49 in the Lower Shutup.
Located in a limestone cliff, notice the dense smoke black on the ceiling.

whether these were active prehistorically, it is likely they were. Clusters of sites at these particular locations suggest that these were more desirable site locales. Of the 22 sites recorded in the Fresno Canyon area, 15 are open sites and the remaining seven shelter sites. Categories represented among the open sites include: gravel terrace sites (10), silt terrace sites (three), ridge sites (one), and canyon rim sites (one).

The gravel terrace sites are similar to those in the Solitario, occurring primarily on colluvial gravels that have eroded from the slopes of nearby hills. Cultural debris on these sites typically consists solely of an abundance of flaking debris scattered about the surface, and all sites appear to be heavily eroded and are manifested on the surface. Gravel terrace sites include Sites 41PS30, 41PS35, 41PS39, 41PS41, 41PS157, 41PS158, 41PS160, 41PS162, 41PS163, and 41PS167. Only one of these sites differs considerably in its cultural debris from the others. Site 41PS167 appears to have been a quarrying activity site; the only material observed on the site is a yellowish chert that has been knocked loose from an outcrop in the limestone. Numerous large flakes and cores are present, but few flakes represent artifact production. No flakes exhibited post-detachment modifications such as edge trimming or thinning.

Also interesting to note is the association of several bedrock mortars with Site 41PS30. This site is located on a gravel bench overlooking the bed of Chorro Canyon. Water is presently available in the canyon, and the bedrock mortars are in the exposed rock of the stream bed. This is the only association of ground stone implements with gravel terrace sites found in the Fresno Canyon area.

Three sites are situated on silt terraces. Two of these, Sites 41PS159 and 41PS166, are located at the respective confluences of Arroyo Primero and Arroyo Segundo with Fresno Creek. The third, Site 41PS156, is located near the northern end of Fresno Canyon at the confluence of a small tributary with Fresno Creek. It is interesting that all three are on the western side of the creek and that Sites 41PS159 and 41PS166 both occur just above the confluence. All of these sites exhibit an abundance of flaking debris, bifacially thinned flakes, and ground stone implements (mano and metate fragments). Site 41PS156 yielded numerous metate fragments, and several bedrock mortars were found in the stream bed. Metates occur both in slab and basin form, and fragments of each type have been observed on all three salt terrace sites. Also observed on these silt terrace sites were angular fire-cracked rocks, possibly scattered hearth stones.

An unpaved road, once the Marfa to Lajitas stage line, cuts across Site 41PS159. Today this road is kept open by bulldozers which have caused considerable damage to a portion of the site. It did, however, enable the survey party to observe the depth of the site which appears to be at least a meter in places. All of these silt terrace sites undoubtedly have been heavily surface collected by local relic-hunters as all are easily accessible. Local informants have mentioned that everyone knows of these sites. The fact that few finished artifacts were found on the sites seems to substantiate this.

One site is designated a canyon rim site. Site 41PS47 is situated on the relatively flat northern rim of Chorro Canyon. Material culture is extensive on this large site which covers an area of approximately 30,000 square meters. Numerous concentrations of flaking debris and fire-cracked rocks were observed, in addition to several large metate fragments. The site is situated atop an igneous formation, known as the Rawls Formation, which is typically dark in color. Artifacts and chipping debris, primarily of novaculite and gray chert which are generally light in color, contrast sharply with the dark igneous rocks. Near the edge of the canyon rim several piles of rocks were observed. Whether they are associated with the site or perhaps were placed there by early ranchers or sheepherders is unknown. All of the artifacts are on the surface of the site, which is in an eroded condition. However, as mentioned, definite concentrations of artifacts and debris are discernible, and controlled surface collections and maps should provide invaluable information about the site.

Site 41PS168 is the only example of a ridge site recorded during the survey. This is not to say that others do not exist; the survey party was unable to examine much of the uplands where it is likely that similar sites occur. This site is located on a high ridge composed of dark brown igneous rocks which are lava flows of the Rawls Formation, and is north of and overlooking Arroyo Primero and Chorro Canyon. The site is characterized by a dense scatter of lithic debris in a relatively small area. Most of this flaking debris is in the form of small chips and flakes, although some worked flakes and several thin bifaces were observed. One of these thin bifacially-worked specimens was a large well-made projectile point with an expanding stem and notches cut upwards from the base.

Seven rockshelters were located during the Fresno Canyon survey. Three of these, Sites 41PS40, 41PS164, and 41PS165, are situated on the eastern side of Fresno Creek. Site 41PS40, recorded by the General Land Office in May, 1973, is an interesting geologic setting (see discussion in Geology Section of Natural Areas Survey Report on the Fresno Canyon area). After the uplift that domed the Solitario, a great block of Buda Limestone and Del Rio Clay slid down toward the present location of Fresno Creek where it thrust into flaggy limestones of the Boquillas Formation. Subsequent erosion along the sides of Fresno Creek created a westward-facing shelter in this outcrop near the edge of the stream bed (Fig. 4). The first stream terrace is approximately 8 to 10 m above the stream bed so the site provides good shelter without danger of being flooded. Judging from the large amount of fire-cracked rock and ash on the talus slope, Site 41PS40 has had considerable and frequent use.

Inside the shelter are numerous pictographs of hand prints. Two methods of producing these pictographs were observed. Most have been formed by the negative relief method and have a white painted background; the others are impressed directly on the ceiling (Fig. 5). Red, black, and white pigments were used, and it is interesting to note that all of the negative relief pictographs are of left hands, perhaps suggesting that their maker(s) were right-handed. The impressed hand prints occur as both left and right hands. The ceiling is heavily smoke-blackened, providing a dark background for the negative relief hand prints. Numerous scratches and grooves are present on a large limestone boulder in the center floor as well as in the limestone sides and back wall of the shelter. These probably are the result of sharpening bone or wooden implements. At least 18 bedrock mortars were observed in the limestone stream bed in front of the shelter (Fig. 6).

Site 41PS164 is located opposite the confluence of Arroyo Primero and Fresno Creek. The shelter itself is semicircular and is located at the base of a 20-m limestone cliff in an area that looks like a small box canyon. Much of the shallow overhang was created by the backwash of water flowing over the top of the cliff, probably only during heavy rains.

Local sheepherders have fenced the mouth of the small box canyon and, judging from the amount of dung on the floor, the shelter has seen considerable use as a natural corral. Springs are presently running in Fresno Creek near the shelter, making the area desirable for use as a corral. Prehistoric cultural debris includes a few scattered chert flakes and several whole and fragmentary manos and metates (Fig. 7). Obscure pictographs were observed on the north wall along with some present day grafitti. Severe spalling of the limestone, in addition to exposure to the weather, has destroyed many of these pictographs.

Approximately 200 m to the west is Site 41PS165, a small shelter on the eastern edge of the stream bed of Fresno Creek. This shelter has been used by sheepherders also, evidence of use being a rock wall built over the entire entrance to a height of approximately one meter. During periods of severe flooding the shelter more than likely gets washed out, as indicated by silt deposits on the shelter floor. Although several chert flakes were observed, most of the cultural debris undoubtedly has been swept downstream. Six bedrock mortars were observed in the stream bed and are associated with Site 41SP165 and probably Site 41PS164.

Slightly west of and overlooking the confluence of Chorro Canyon and Arroyo Primero is Site 41PS32, a cup-shaped shelter situated on the side of a large igneous hill of the Rawls Formation. Since the shelter is in the cliff face, the only access is from the back side of the hill where a small path leads along a narrow ledge to the entrance. Chipping debitage from the shelter is scattered down the back side of the hill almost to Arroyo Primero. The site probably has been heavily surface collected by local relic-hunters; there are no diagnostic tool forms available, and chipping debris was observed stacked into small piles on rocks near the shelter entrance. There is no midden inside the shelter itself, only exposed bedrock.

Near the northern canyon rim overlooking Chorro Canyon and just south of Site 41PS47, is a small shelter, Site 41PS46. A rock wall, apparently built by sheepherders, surrounds one side of the entrance (Fig. 8), and a large talus slope containing numerous fire-cracked rocks, ash and chipping debitage extends approximately 20 m downhill in front of the shelter. Several manos and metate fragments were observed in the talus as well as one large whole slab metate near the entrance. A close inspection of the debris in the talus slope should yield invaluable information about the prehistoric activities at the site.

Arroyo Segundo is a tributary of Fresno Creek, draining the western uplands. Numerous springs were observed in the stream bed, along with several large depressions in the bedrock which have created pools, some of which were 10 to 12 ft deep in June, 1976. The walls of the tributary canyon are extremely steep, providing few locations suitable for habitation and restricting entrance into the area to the mouth of the arroyo.

Site 41PS161 is situated approximately 50 m above the stream bed in a tuffaceous conglomerate atthe base of the igneous Rawls Formation (Fig. 9). The midden in the shelter appears to be intact, and artifacts include chipping debris, projectile points, ground stone fragments, and perishables such as worked bone and wood and vegetal remains. Numerous charcoal flecks were observed in the shelter interior, and the ceiling is heavily smoke-blackened. All perishable artifacts are in excellent shape, suggesting stabilized moisture conditions within the shelter, and

FIGURE 4

Site 41PS40 looking east from Fresno Creek.
Stream bed is of Buda Limestone and the Boquillas Flagstone Formation lies directly on top of the stream bed.

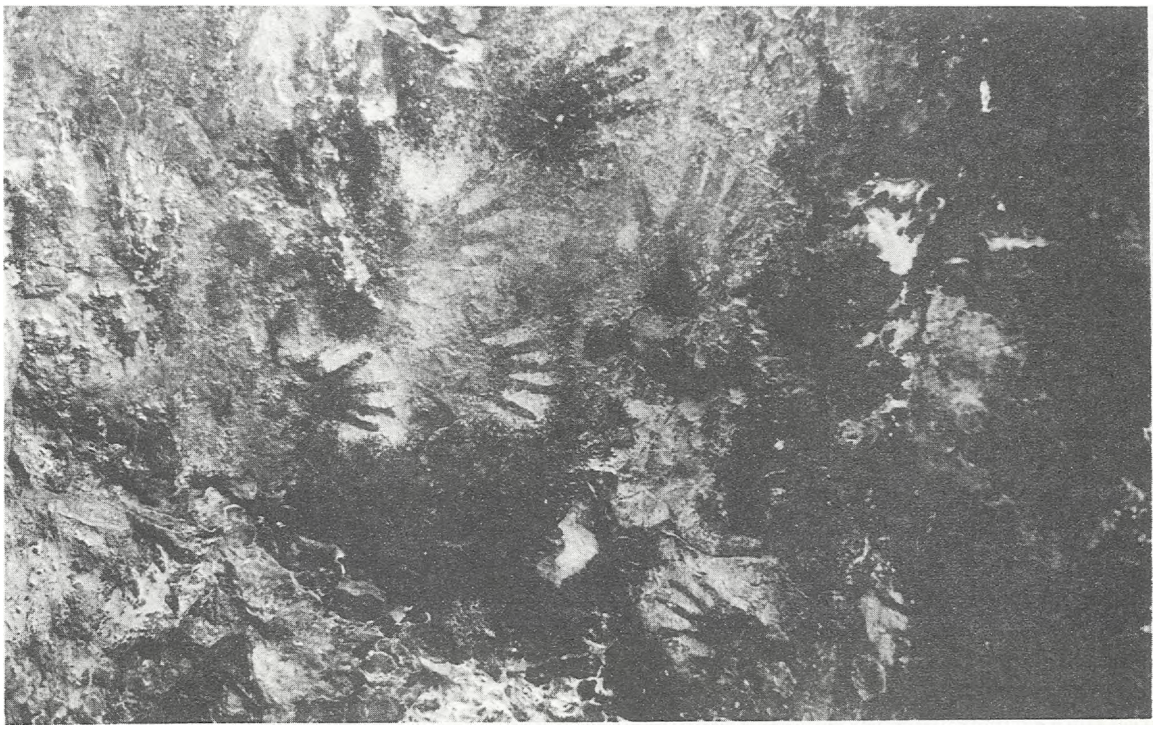

FIGURE 5

Pictographs on the ceiling of Site 41PS40; visible are examples of both impressed and negative relief. All negative reliefs are of left-hand prints. Dark background is smoke black.

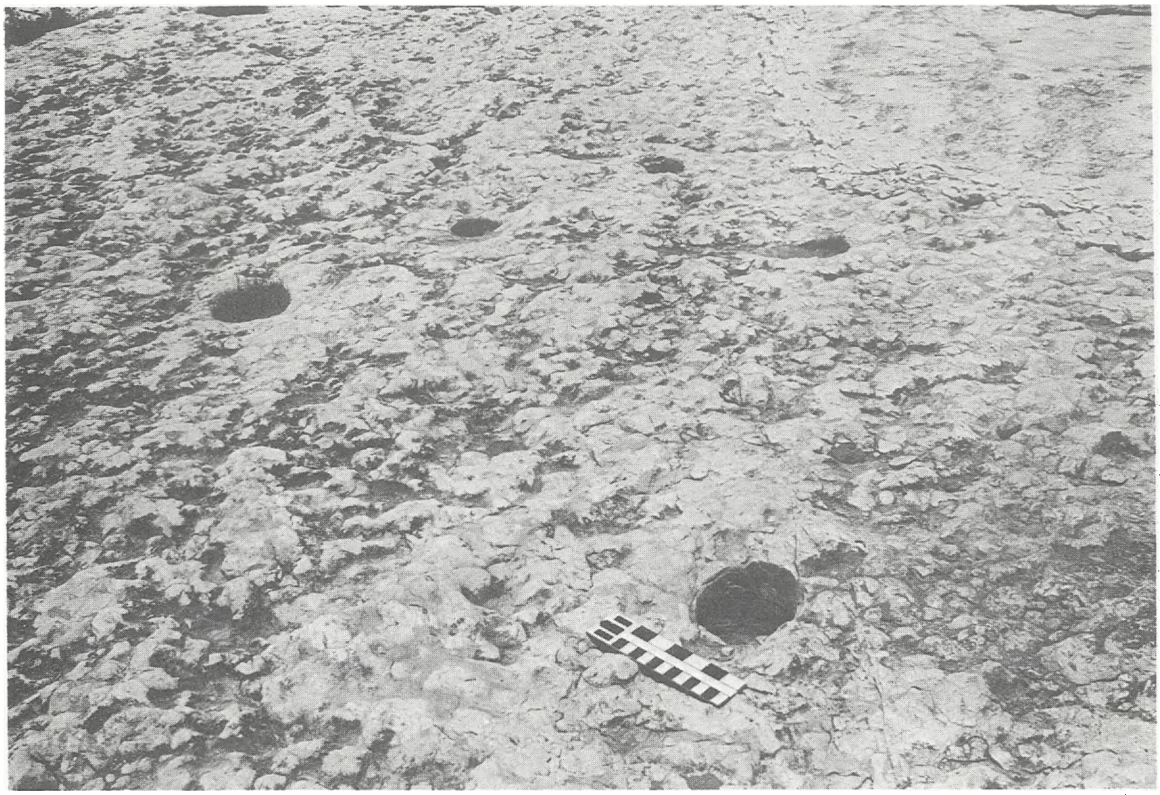

FIGURE 6

Streambed in front of Site 41PS40 showing five of the eighteen bedrock mortar holes located there.

FIGURE 7

Metate and mano from Site 41PS164.
Mano was placed on top of the metate for photograph.

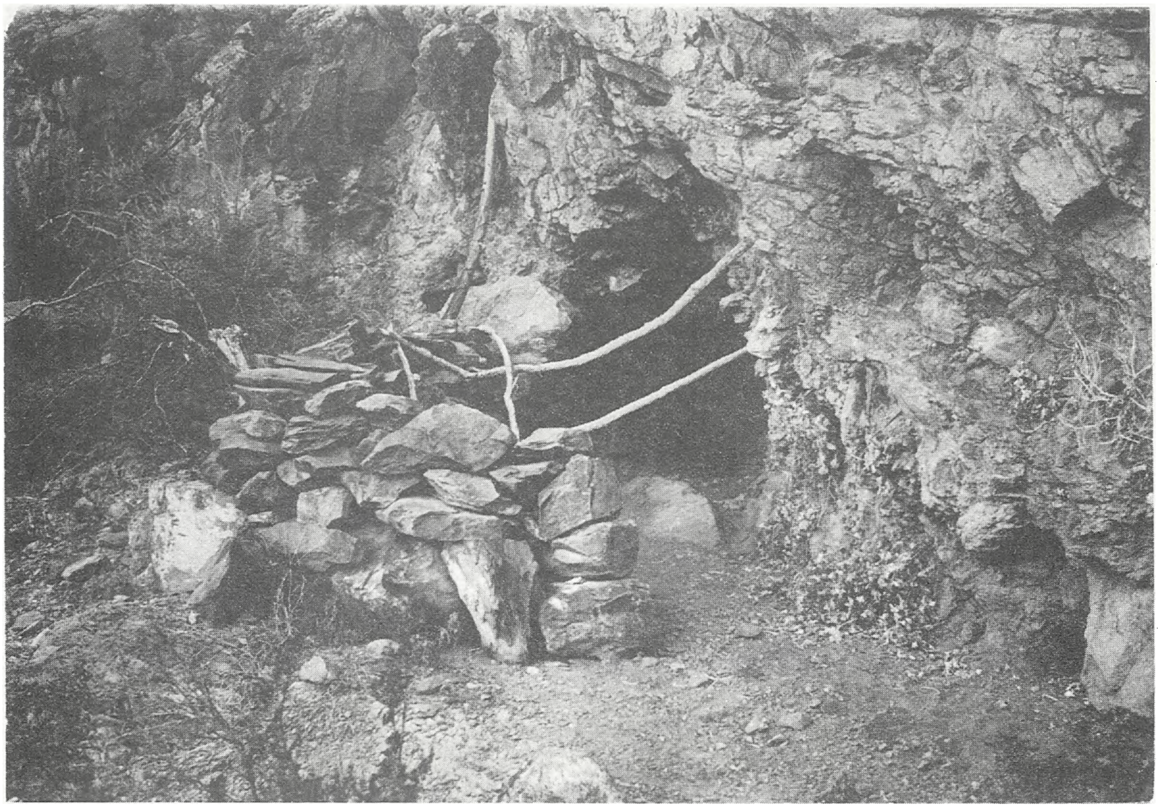

FIGURE 8

Site 41PS46. Rocks and sotol stalks were placed by local sheep herders.
Shelter is situated in an unstable cliff of the igneous Rawls Formation.

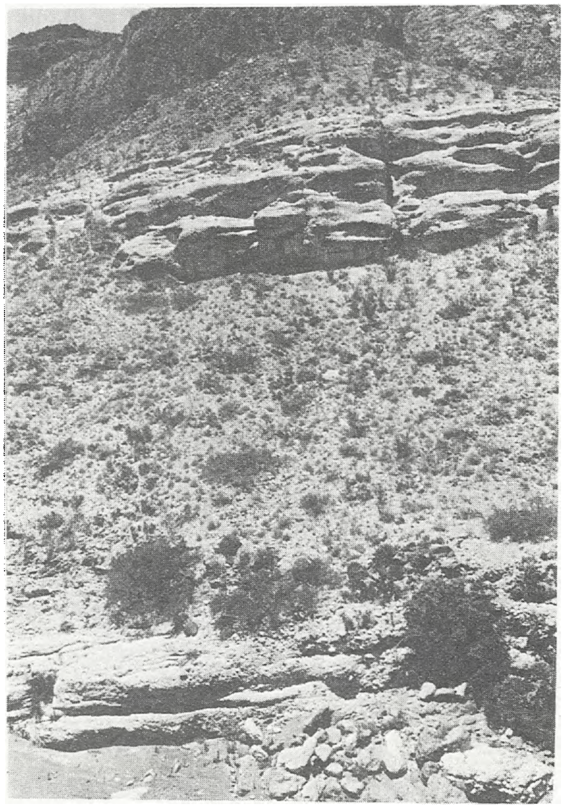

FIGURE 9

Site 41PS161. Shelter is at base of the tuffaceous outcrop.
The streambed of Arroyo Segundo is at the bottom of the picture.
View is looking north.

the possibility of more well-preserved specimens appears to be good.

The largest and most impressive rock shelter to be found in the Fresno Canyon area is Site 41PS169 (Fig. 10). This large shelter is situated in an unwelded tuffaceous outcrop overlooking the upper reaches of Arroyo Segundo approximately 4 km upstream from Site 41PS161. This site is actually composed of three shelter areas, the largest yielding numerous examples of rock art. The shelters and their talus slopes contain extensive amounts of dark, ash-stained soil and fire-cracked rocks, along with chipping debitage, ground stone fragments, bedrock mortars (Fig. 11), and trimmed flakes. Inside the shelters were perishables such as worked bone and cane and vegetal remains.

The most interesting aspect of this shelter is the pictographs, several of which portray men on horseback (Appendix 2, panels 1, 4, 5, 6, and 7), definitely dating them at least to European contact times (post-1600) in the area. Whether they depict Spanish horsemen or whether the aborigines had horses is difficult to determine since this is the only post-contact archeological site that has been recorded in the area. Red, black, and white pigments were used in the drawings, black being the predominant color. For accurate reproductions of these pictographs, see Appendix 2 of this section.

LITHIC MATERIAL SAMPLE ANALYSIS

The availability and desirability of lithic materials used for tool production is a problem that until recently has not been included in many archeological reports. Much can be learned from such a study, for an understanding of the relationship between prehistoric groups and their environment is of primary concern to all archeologists. Lithic materials are natural resources, and prehistoric people had to know something about those natural resources to extract them and use them. Whether materials are locally available or are obtained elsewhere either directly or by trade may tell something about the social and/or political considerations of a group, such as group movement or trade relations. Identifying the sources of lithic materials and examining the patterns of exploitation may yield information, such as site function, and explain certain site locations, thus making possible more accurate descriptions and reconstruction of prehistoric societies.

The majority of the lithic material used in the Solitario and Fresno Canyon areas can be classified under the general heading of chert. Several variations can be identified and placed into certain parent geologic formations; however, outcrops of these formations are available in numerous places, so it is difficult to determine actual quarry areas. It is possible to make only general statements concerning site location and settlement patterns from this information. Unfortunately, there is no evidence that any of the materials collected in the Solitario and Fresno Creek are from exotic resource areas. All probably can be found in the immediate area. This statement, however, must be considered tentative until a more intensive study can be performed.

Several criteria are involved in the analysis of lithic sample characteristices, and many of them can be accomplished in the field. Collections of materials are made from sites and also from possible resource or quarry areas in the hope of finding the parent sources of the materials used on the sites. With the naked eye or using low magnification, one can determine characteristics such as color, texture, fossil inclusions, translucency, and bedding and fracture patterns (Blakeman 1975:1).

Solitario

More detailed descriptions of the sites in the Solitario are described in the companion volume on that area (Hudson 1976). As mentioned before, chert, especially in the Solitario, is so abundant that is is difficult to say where it comes from. We can only determine the source in a general area. In the Solitario the material occurring with the highest frequency is a white siliceous chert known as Caballos Novaculite. Outcrops of this are numerous. It occurs on most of the open, gravel terrace sites, having eroded from the nearby slopes of the chert ridges in the interior of the Solitario. It is likely these materials were obtained from the surface of these sites as well as in outcrop areas. Another chert, the black chert in the Maravillas Formation, occurs below the Caballos Novaculite, and both are found on the sites in raw form. It is interesting to note that both are highly fractured, a property that may account for the consistently small flakes and tools formed from these materials. A third type of chert is a light gray material found in relative abundance and coming from chert nodules eroding out of the Cretaceous limestones in the area. Site 41PS140 (Fig. 12) and a section of the Righthand Shutup were observed as quarry areas for these nodules. The gray chert generally has better knapping characteristics than the novaculite, and many of the larger well-made tools are chipped from this material. Other knappable materials observed on the sites in the Solitario are chalcedony, opalite, and petrified wood, and, although all are to be found locally, no quarry sites were observed.

Food grinding implements, primarily bedrock mortars, are found only on Sites 41PS144 and 41PS150 in the Solitario. Several portable basin and

FIGURE 10

Site 41PS169 looking southwest.
Pictographs cover the entire length of the back wall of this shelter.
During severe rains large amounts of water pour over the gap
in the upper right of the photograph.

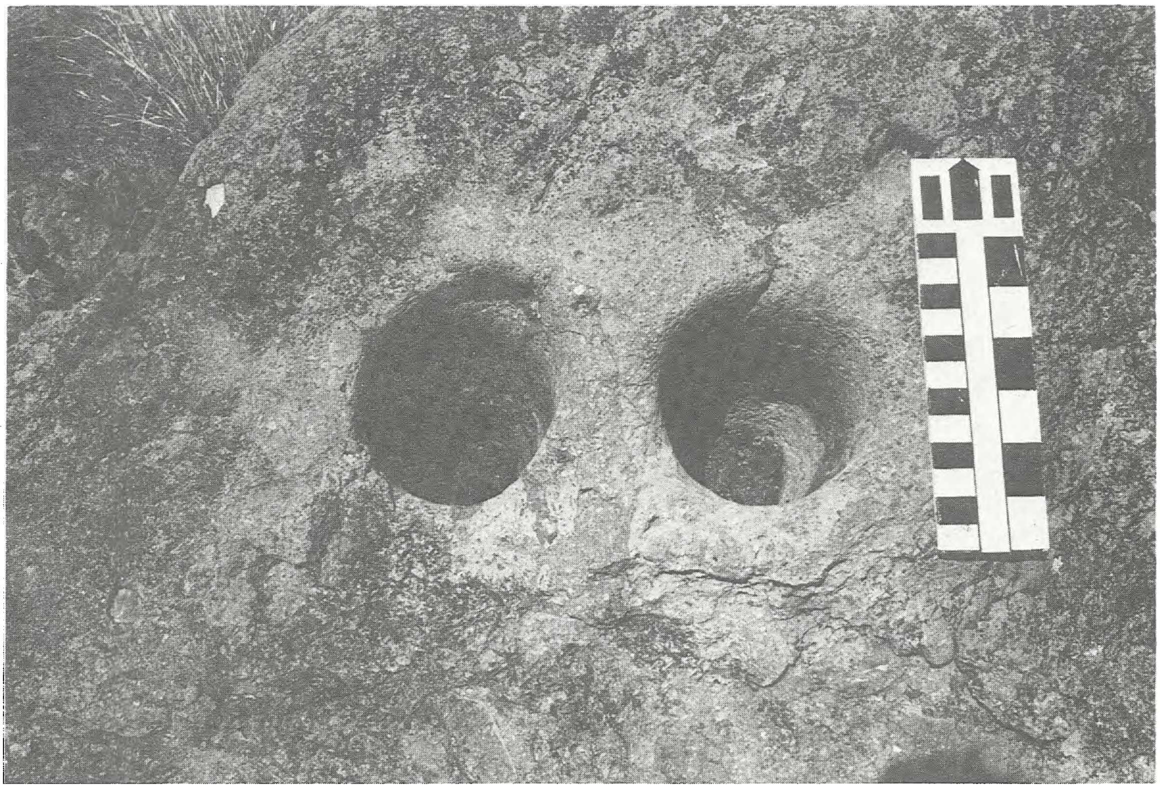

FIGURE 11

Bedrock mortars in tuffaceous rock at Site 41PS169.
Depth of each is approximately 30 centimeters.

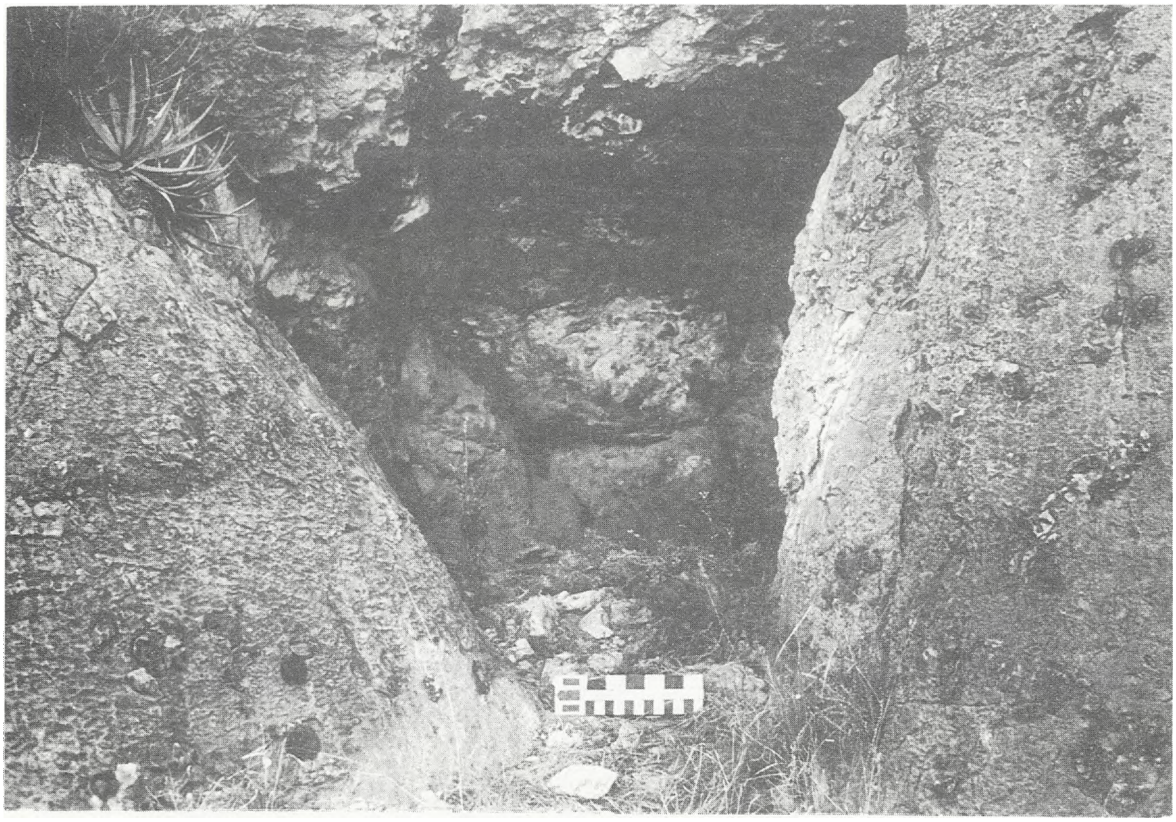

FIGURE 12

Site 41PS14 looking east.
Note the chert nodules exposed in the limestone and smoke black on the ceiling.

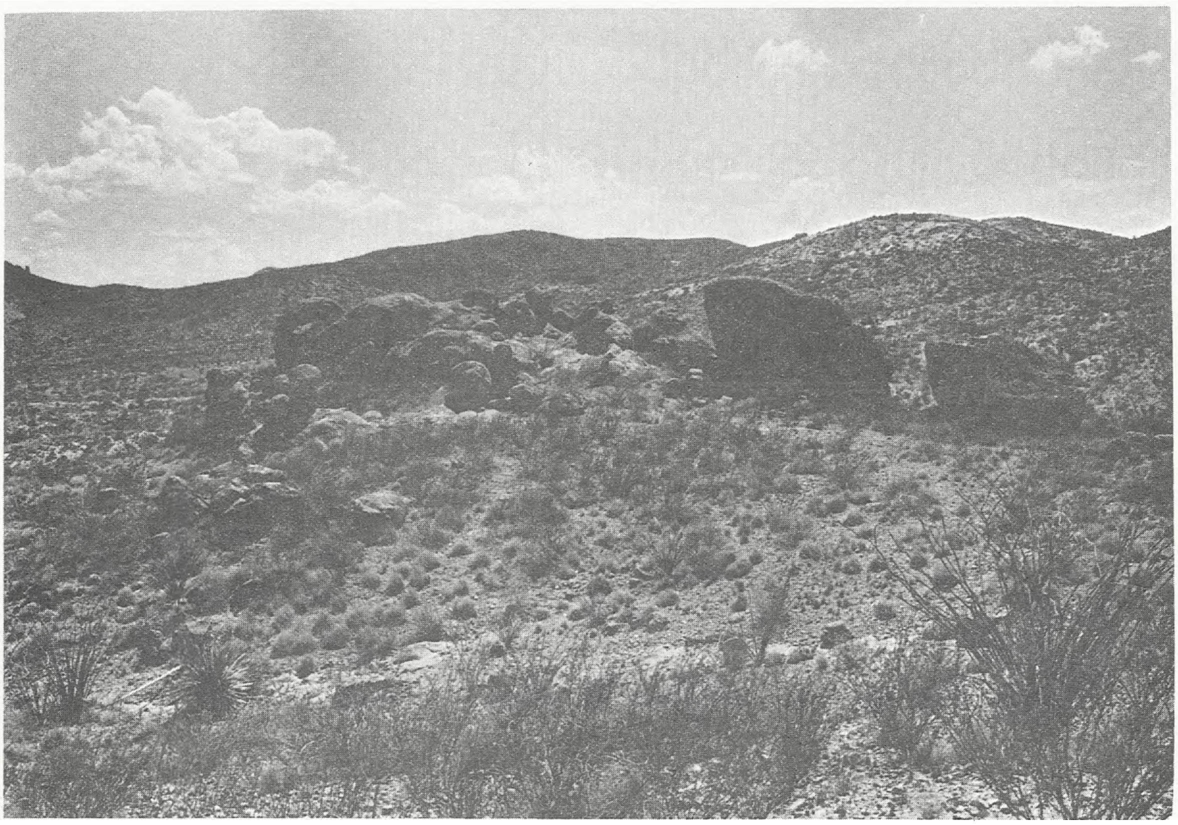

FIGURE 13

View of Unit A, Site 41PS150, looking northwest.
A large shelter is situated under the large boulder to the right.
Rock is a tuffaceous conglomerate.

slab metates both of sandstone and unwelded volcanic tuff were observed on these sites. Bedrock mortars in the Solitario were found only in the tuffaceous outcrop at Site 41PS150 (Fig. 13).

Fresno Canyon

Archeological sites in Fresno Canyon offer a wider variety of lithic materials than do those in the Solitario. This may result from the availability of volcanic rocks in the nearby Bofecillos Mountains. Light gray chert is the most frequently used material. No quarry sites were located for this type but more than likely it is coming from chert nodules in the limestone of the area. In addition to the gray chert, other colors of siliceous chert include brownish and yellowish types. Site 41PS167 is a quarry site for the yellowish variety. Other knappable materials available in the Fresno Canyon area are chalcedony, opalite, limestone, petrified wood, and various colors of agates. All are available locally. Black, red, and black- and red-banded volcanic glass occurs throughout the area at the base of the lava flows (Dwight Deal 1975, personal communication; see also Geologic Section of Fresno Canyon Report). The source was not discovered during the survey, but the abundance of these materials on the sites suggests that it was readily available.

Groundstone implements were observed at many of the large open sites as well as sheltered sites. Materials for these included unwelded tuffs, sandstone, and limestone for the metates, and unwelded tuffs and igneous rocks for manos. Bedrock mortars were observed in both limestone stream beds and in unwelded tuffaceous outcrops.

In summary, it is difficult to determine the actual sources of many of the lithic materials found on sites in the Solitario and in Fresno Canyon. This is due to the geological diversity, the numerous outcrops within the areas, and to the easy availability of the cherts and siliceous volcanic glass.

Specific materials may have been desired for certain purposes, and prehistoric inhabitants in the study area did show a preference for the siliceous and volcanic glass materials. This is obviously a function of the better fracturing qualities of these rocks. Most of the finished artifacts (i.e., projectile points, thinned bifaces, scrapers, etc.) are formed from gray chert and novaculite.

There is also much variation within the major groups of materials. For instance, there are numerous color shades in gray chert and in Caballos Novaculite. To make it even more difficult, these variations in color sometimes occur within each outcrop. Microscopic, and possibly trace element, analysis would be required to determine parent sources for some of these lithic materials, but this is not necessary in such a small area as long as one is dealing with local materials. Only when exotic materials appear on the sites should such an effort be made.

DISCUSSION

Information gathered from archeological sites in the Solitario and upper Fresno Canyon tentatively suggest a long history of cultural occupation. Sites occur in rockshelters, alluvial silt terraces, colluvial gravel terraces, uplands, and in constricted canyons, representing nearly all environmental niches to be found in the area.

Although it would be difficult to place these sites in any chronological order at this time, diagnostic artifacts observed on sites suggest at least intermittent occupation over long periods of time. These artifacts, along with the large quantities of chipping debitage found on most sites, suggest that the prehistoric inhabitants in Fresno Canyon and the Solitario probably had an economy based on small-game hunting and foraging, utilizing every available natural resource. Doubtless the inhabitants manipulated their environment to some degree, but, for the most part, the present evidence suggests that they followed what archeologists have termed an Archaic hunting/gathering mode of subsistence. Judging from the homogeneity of the artifact inventory, there seems to have been a persistence of cultural systems based on subsistence patterns that were strongly influenced by the environment. No evidence of domestication of plants or animals has been recorded in the area, and no ceramics usually associated with agricultural societies were found on any sites. The xerophytic climatic conditions and the apparently simple technological level show numerous similarities with the Desert Cultures of the western United States which adapted to a similar arid or semiarid habitat (Martin and Plog 1973:69-80).

Likely, these prehistoric inhabitants were formed into small groups of kin-related people whose search for food was almost continuous. Lack of a dependable long-term food source necessarily kept these groups small and undoubtedly kept them moving about seasonally, exploiting different resources at certain times of the year. Like the Desert Culture, they no doubt kept their personal property minimal and portable.

It is important to look at these sites within these areas not as entities but as part of a larger settlement system. These sites cannot be explained separately for they fit into a pattern governed by two environments, a social one and a natural one (Plog and Hill 1971:9).

Sites are located with respect to natural resources, in addition to being located with respect to each other.

Several hypotheses are suggested by the information gathered from these sites. One is that the Solitario was a special utilization area characterized by limited activity sites, generally of a utilitarian nature, and that temporary forages were made into it by people living outside the Solitario rim to obtain particular foods and/or to gather desirable lithic materials. The present land forms and resources suggest that more desirable and permanent living conditions could have been found in Fresno Canyon, largely because of more reliable water sources. Except for several isolated areas (for example Site 41PS150), the Solitario presently is suitable only for short-term occupation. As presented in the discussion of the Shutups, access into the Solitario is most easily gained through them. Routes coming in from the north are also probable since the rime is less steep in this area.

It can be seen that the Solitario and Fresno Canyon areas are two quite distinct areas. Information in Appendix 1 will help clarify these differences. Some of the distinctions noticed during the survey are that few of the open sites in the Solitario exhibit any vertical depth. In fact, only one, Site 41PS144, shows any depth at all. Also, the rockshelters in the Solitario generally tend to be smaller and show fewer signs of occupation (cultural debris, smoke-black, etc.) than do those of Fresno Canyon. Interesting to note, also, is that no pictograph sites were recorded in the Solitario, while three sites in Fresno Canyon had pictographs. A scarcity of ground stone artifacts was observed in the Solitario also.

All of these observations support the hypothesis that the Solitario was primarily a special utilization area with intermittent water sources. Fresno Creek to the west is a major drainage for the area, and it likely was a more permanent water source.

Chronologically, the only definite dating of any of the sites is Site 41PS169, where the pictographs of men on horseback (see Appendix 2) indicate at least post-European contact. Other than this, no attempt will be made at this time to date any of the sites except to say they range from historic times back possibly as far as 5 to 10 thousand years ago.

RECOMMENDATIONS

In any archeological study the ultimate goals are to produce an accurate description and reconstruction of prehistoric cultures. The preliminary nature of this survey represents a first step towards the realization of these goals. Several tentative suggestions are made here in order to familiarize readers with some of the questions of concern to archeologists while trying to reconstruct past human cultural patterns.

Studies involving prehistoric environmental adaptations are presently being pursued by many archeologists as a means of reconstructing aboriginal societies. With help from scientists of various disciplines, such as botany, biology, geology, and palynology, to name a few, archeologists are able to gather a substantial amount of information with which to work. Questions such as what the environment looked like at various stages of human occupation; what environmental resources were used; how society was organized to exploit these resources, and how the resources affected social organization and site distribution are presently being posed (Martin and Plog 1973:155).

It is difficult to determine the function and chronology of each site when only a general reconnaissance such as this has been performed. It is obvious that much additional work is needed. A preliminary survey only enable general inferences about prehistoric cultures.

Archeology is a fragile resource that cannot withstand any outside pressures. To alter land forms by construction or to allow relic-collecting (vandalism) on archeological sites will have a detrimental effect on the cultural resources. Archeological sites are nonrenewable resources and a site, once disturbed, is destroyed forever. In a sense, professional archeologists who excavate sites also destroy them; if the information is not properly collected, there is no way to go back with a different approach. If for any reason an excavation or survey is not properly executed, valuable information will be irretrievably lost.

The State of Texas is responsible for conducting organized research on public lands and for protecting cultural resources. Generally, research should be in the form of intensive surface surveys with subsurface testing and subsequent excavations of selected or endangered sites. Stabilization of these sites where necessary also is important. The educational potential of these significant archeological resources should not be ignored but pursued, so that the cultural history of the area may be reconstructed and preserved.

Recommendations for individual sites of the Solitario and the upper Fresno Canyon area are given in Appendix 1. Subsequent work should consist of an intensive on-foot survey with controlled surface collecting and limited subsurface testing to determine the archeological potential of each site. Special attention should be devoted to those areas that were not surveyed, for instance, the numerous ridge tops and uplands in the Solitario and the uplands to the west of Fresno Creek. Also important are the mouths of the Lefthand and the Lower Shutups and the ridges above them. Without adequate information from all environmental niches in both areas, only a small portion of the prehistoric record can be established. The Solitario and Fresno Canyon areas have long been important to the history of the area, geologically, biologically and culturally. It is to be hoped more intensive research will be conducted to help us understand and more fully appreciate it.

ACKNOWLEDGMENTS

The primary purpose of this archeological reconnaissance has been to locate and describe the archeological resources of the Solitario and upper Fresno Canyon areas in Brewster and Presidio counties, Texas, and to evaluate the desirability and feasibility of a more intensive archeological investigation of these aboriginal sites. This research can help in the development of a more complete record of the cultural history of the prehistoric inhabitants who once occupied the study area.

In the field, much appreciated assistance was provided by Mike Mallouf, archeologist for the Texas Historical Commission, who was present during all of the field work. Success in the field was also made possible by the thoughtful and cooperative assistance of botanists Mary Butterwick and Stuart Strong; zoologists Wayne Hanselka, Jack Burns, and Jim Scudday; and geologist Dwight Deal. Much appreciation goes to Ralph Hager and Joe Mimms of the Big Bend Ranch on whose land the survey was made. Ralph made our stay enjoyable and provided much assistance in locating some of the important sites.

Albert Rubio of Austin deserves special thanks for giving freely of his time to photograph some of the archeological sites in the area.

Also, thanks go to Bob Mallouf and Curtis Tunnel of the Texas Historical Commission who contributed many useful suggestions and criticisms, in addition to editing the final draft of this report. Barbara Walker, also of the Texas Historical Commission, assisted in the editing and did much of the typing.

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APPENDIX I

PREHISTORIC SITES IN THE SOLITARIO, THE SHUTUPS, AND UPPER FRESNO CANYON

from surface observations only

Site Number	Site Elevation (Above MSL)	Horizontal* Distance From Water (Meters)	Vertical* Distance Above Water (Meters)	Kind** of Site	Occupation Area (Approx. Sq. Meters)	CULTURAL DEBRIS: Perishables	CULTURAL DEBRIS: Ground or Pecked Stone	CULTURAL DEBRIS: Chipped Stone Artifacts	CULTURAL DEBRIS: Fire-cracked Rock	CULTURAL DEBRIS: Flaking Debitage	CULTURAL DEBRIS: Rock Art	CULTURAL DEBRIS: Lithic*** Materials Present on Site	Present Condition	Recommendations
THE SOLITARIO														
41PS141	4550	None (30)	None (10)	GT	1,000	None	None	Yes	None	Yes	None	N, G, M	Construction Damage	No further work
41PS142	4550	None (20)	None (5)	GT	2,400	None	None	Yes	None	Yes	None	N, M	Eroded	No further work
41PS143	4370	None (15)	None (10)	GT	500	None	None	Yes	None	Yes	None	G, N	Partially Eroded	Controlled collection
41PS144	4280	None (3)	None (6)	GT	1,500	None	Yes	Yes	Yes	Yes	None	N, G	Slightly Eroded	Controlled collection and limited testing
41PS145	4490	None (400)	None (65)	SH	75	None	None	Yes	Yes	Yes	None	G	Intact	Controlled collection and limited testing
41PS146	4280	None (15)	None (10)	GT	1,800	None	None	Yes	Yes	Yes	None	N, G	Eroded	No further work
41PS147	4221	None (10)	None (30)	GT	100	None	None	None	None	Yes	None	N, G	Eroded	Controlled collection
41PS148	4480	None (200)	None (40)	SH	15	None	None	Yes	None	Yes	None	G	Partially Eroded	Controlled collection
41PS149	4520	None (20)	None (15)	UL	100	None	None	Yes	None	Yes	None	N, G	Eroded	Controlled collection
41PS150	4440	None (20)	None (30)	SH	20,000	None	Yes	Yes	Yes	Yes	None	N, G, R, B, P, Ch, A	Intact	Controlled collection and limited testing
41PS151	4360	None (25)	None (15)	GT	30,000	None	Yes	Yes	Yes	Yes	None	N, G, B, Ch	Partially Eroded	Controlled collection and limited testing
41PS152	4320	None (200)	None (50)	UL	100	None	None	Yes	None	Yes	None	N, G	Eroded	Controlled collection and limited testing
41BS473	4360	None (5)	None (8)	GT	4,000	None	None	Yes	None	Yes	None	G, N, M	Eroded	Controlled collection
41BS474	4340	None (5)	None (4)	GT	500	None	None	Yes	None	Yes	None	G, N, M	Eroded	No further work
41BS475	4360	None (8)	None (10)	GT	2,500	None	None	Yes	None	Yes	None	N, G, P	Partially Eroded	Controlled collection
41BS476	4420	None (60)	None (30)	UL	15,000	None	None	Yes	None	Yes	None	N, G, P, Ch	Partially Eroded	Controlled collection
41BS477	4400	None (20)	None (10)	SH	1,200	Yes	Yes	Yes	Yes	Yes	None	G, N, M, A, B	Partially Vandalized	Controlled collection and limited testing
41BS478	4800	None (1000)	None (150)	SH	50	None	None	None	None	None	None	None	Eroded	No further work
41BS479	4280	None (175)	None (40)	SH	300	Yes	Yes	Yes	Yes	Yes	None	N, M, R	Intact	Controlled collection and limited testing
THE SHUTUPS														
41PS49	400	None (10)	None (7)	SH	25	None	None	Yes	None	Yes	None	G	Partially Eroded	Controlled collection and limited testing
41PS153	4200	None (30)	None (70)	SH	50	None	Yes	None	None	Yes	None	None	Partially Eroded	No further work
41PS154	4340	None (5)	None (4)	SH	5	None	None	None	None	None	None	None	Eroded	No further work
41PS155	4350	None (3)	None (5)	SH	7	None	None	None	None	None	None	None	Eroded	No further work
41BS480	3800	None (30)	None (15)	SH	1,250	Yes	Yes	Yes	Yes	Yes	Yes	N, G, B	Severely Vandalized	Controlled collection and limited testing

FRESNO CANYON

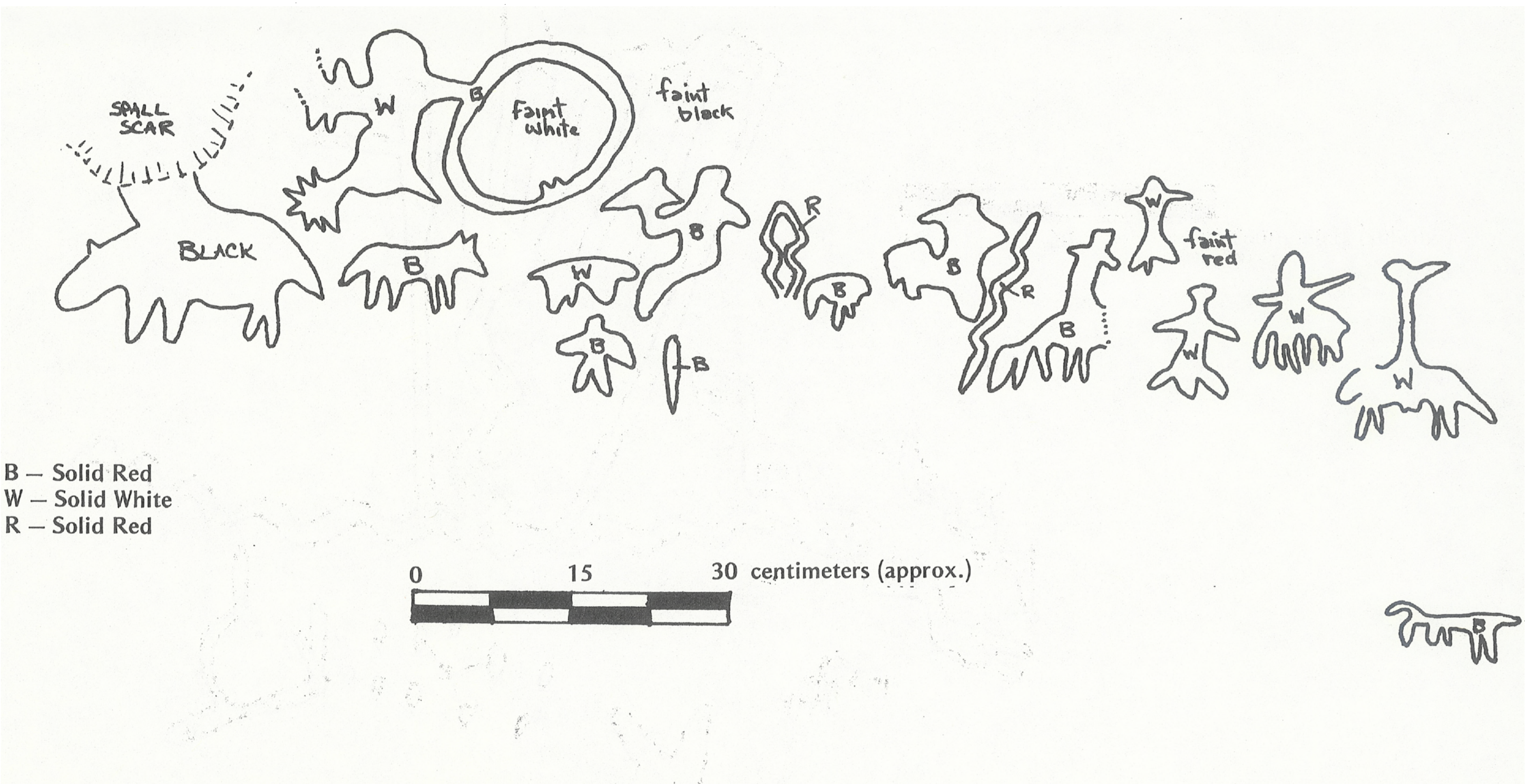
41PS30	3360	10	20	GT	5,000	None	Yes	Yes	None	Yes	None	N, G	Partially Eroded	Controlled collection
41PS32	3400	700 (80)	10 (40)	Sh	50	None	None	Yes	None	Yes	None	N, G, B, R	Eroded	Controlled collection
41PS35	3280	30	80	GT	7,500	None	None	Yes	None	Yes	None	G, N, Ch	Partially Eroded	Controlled collection
41PS39	3300	250	35	GT	1,000	None	None	Yes	None	Yes	None	G, N	Eroded	Controlled collection
41PS40	3692	None (15)	None (20)	Sh	1,000	None	Yes	Yes	Yes	Yes	Yes	N, G, L	Partially Eroded	Controlled collection
41PS41	3760	20	30	GT	7,500	None	None	Yes	None	Yes	None	N, G, R	Partially Eroded	Controlled collection
41PS46	3820	300 (50)	60 (10)	Sh	20	None	Yes	Yes	Yes	Yes	None	N, G, B, R, Ch	Intact	Controlled collection and limited testing
41PS47	3840	30	80	R	30,000	None	Yes	Yes	Yes	Yes	None	N, G, B, R, Ch	Partially Eroded	Controlled collection and limited testing
41PS156	4240	300	20	ST	5,000	None	Yes	Yes	Yes	Yes	None	G, N, B, Y, R, P	Partially Vandalized	Controlled collection and limited testing
41PS157	3800	None (50)	None (40)	GT	15,000	None	None	Yes	None	Yes	None	G, N, Ch	Eroded	Controlled collection
41PS158	3400	None (20)	None (10)	GT	600	None	None	None	None	Yes	None	G, N	Eroded	No further work
41PS159	3360	None (10)	None (4)	ST	7,500	None	None	Yes	Yes	Yes	None	N, G, Ch, P	Partially Intact	Controlled collection and limited testing
41PS160	3360	None (2)	None (5)	GT	1,500	None	None	None	None	Yes	None	G, N	Eroded	Controlled collection
41PS161	3500	45	50	SH	100	Yes	Yes	Yes	Yes	Yes	None	G, N, L	Intact	Controlled collection and limited testing
41PS162	3260	400	30	GT	2,000	None	None	Yes	Yes	Yes	None	G, N, R, Y	Partially Eroded	Controlled collection and limited testing
41PS163	3120	200	40	GT	10,000	None	None	Yes	None	Yes	None	G, N, Y, R, Ch	Eroded	Controlled collection
41PS164	3160	250	20	Sh	200	None	Yes	Yes	None	Yes	Yes	N, G	Eroded Vandalized	Controlled collection
41PS165	3160	5	5	Sh	35	None	Yes	Yes	None	Yes	None	G	Partially Eroded	Controlled collection and limited testing
41PS166	3000	20	5	ST	20,000	None	Yes	Yes	Yes	Yes	None	G, N, R, Y, P, B, Ch, M, A	Partially Eroded	Controlled collection and limited testing
41PS167	3200	20	30	GT	100	None	None	None	None	Yes	None	Y	Partially Eroded	Controlled collection
41PS168	3700	500	100	Rg	1,000	None	None	Yes	None	Yes	None	G, B	Partially Eroded	Controlled collection
41PS169	4100	400 (30)	30 (15)	Sh	8,000	Yes	Yes	Yes	Yes	Yes	Yes	G, N, P, B	Intact	Controlled collection and limited testing

*Numbers in parenthesis indicate hypothetical distances from water at time of prehistoric occupation

**Kinds of Sites (by land form)
GT – Gravel Terrace
ST – Silt Terrace
R – Canyon Rim Site
Rg – Ridge Site
Sh – Shelter Site
UL – Unusual Location Site

***Types of lithic materials on site (refer to section on lithic materials)
M – Maravillis Chert
N – Caballos Novaculite
G – Gray Chert
R – Reddish Chert
B – Black Chert
Y – Yellow Chert
L – Limestone
P – Petrified Wood
A – Agate
Ch – Chalcedony

APPENDIX II



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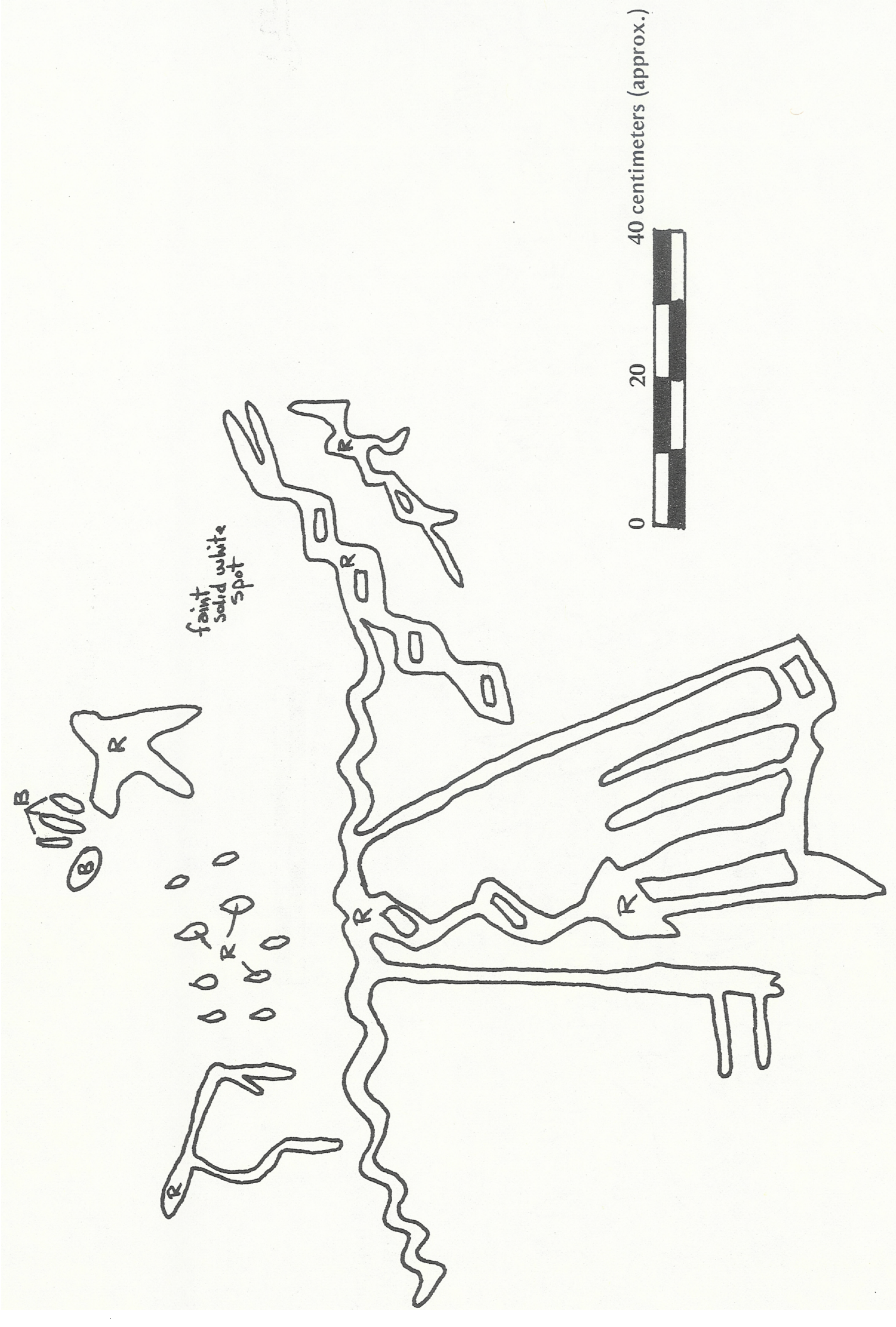

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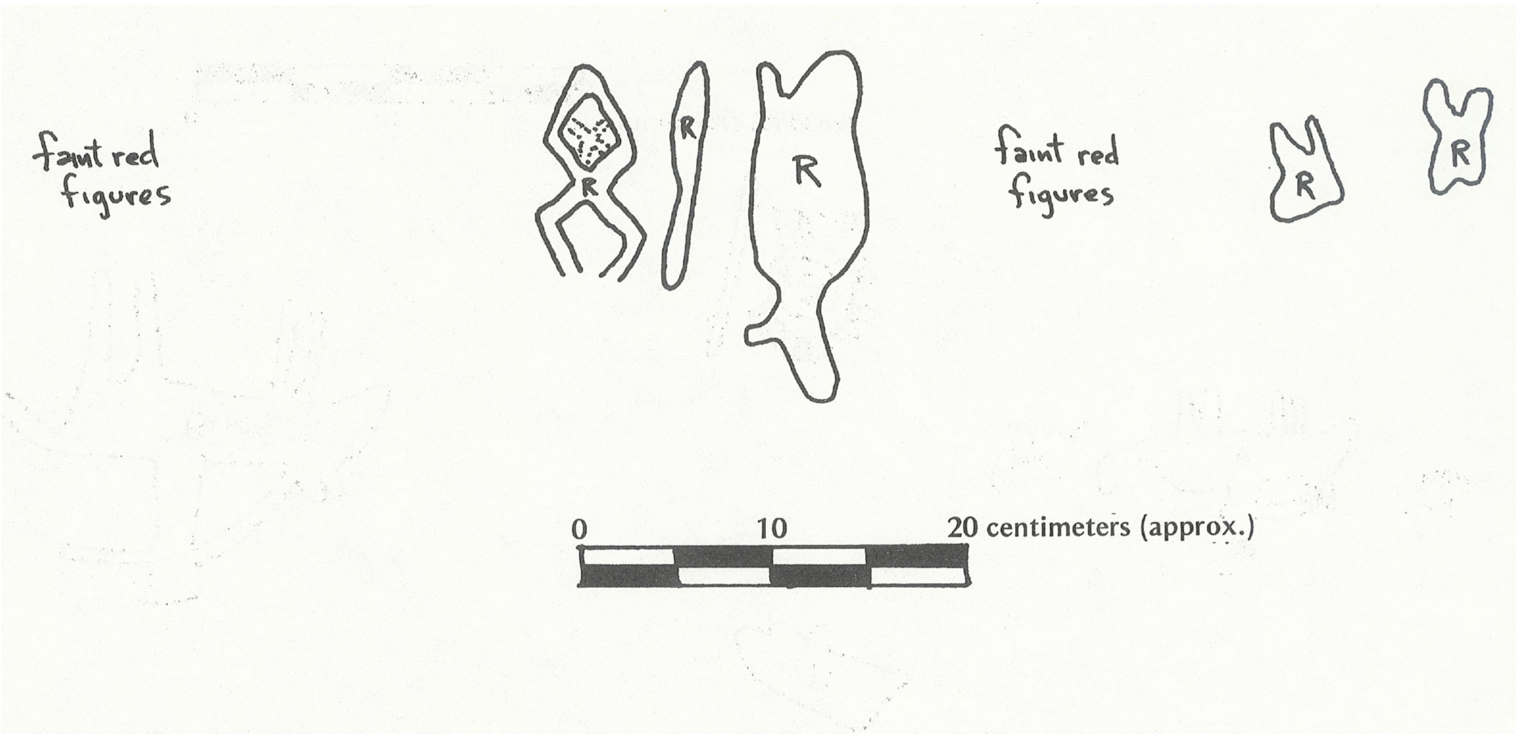

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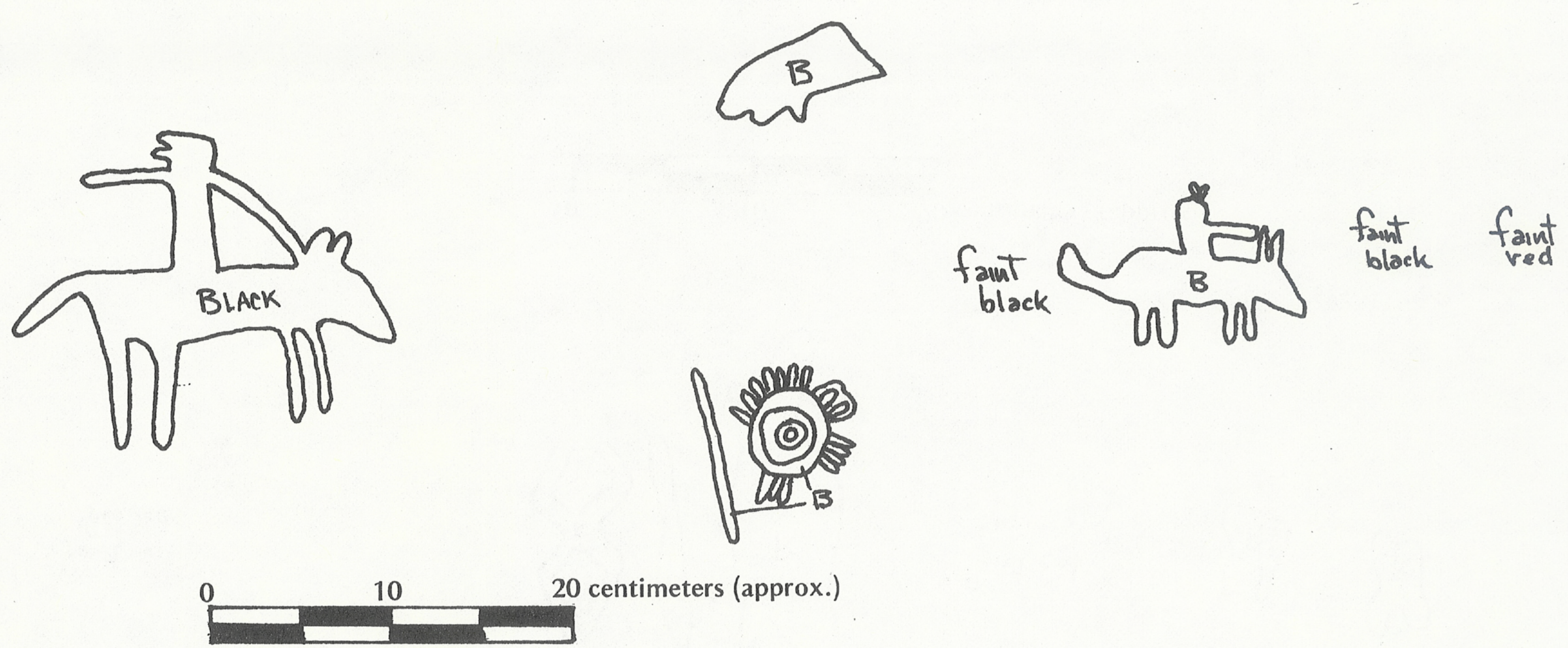

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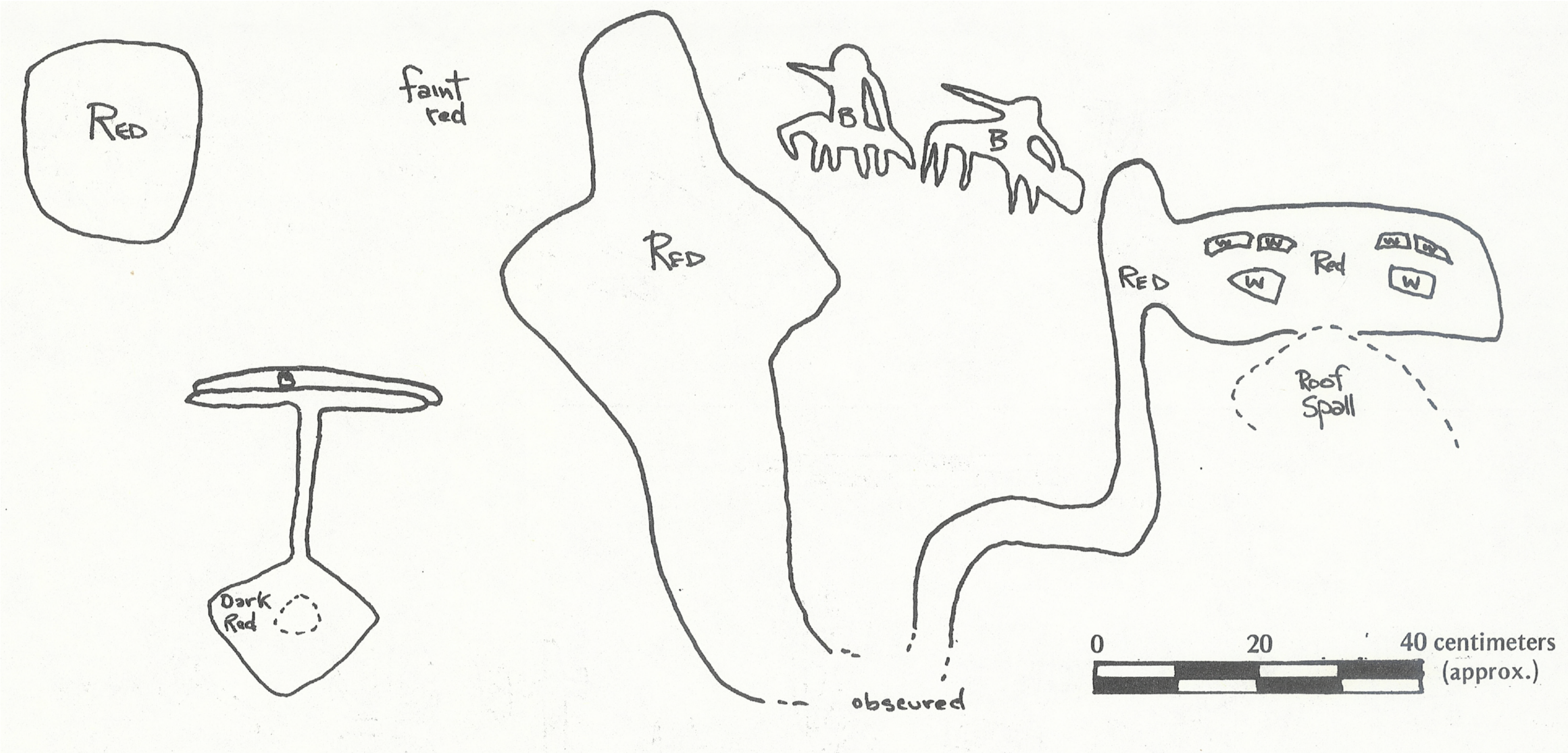

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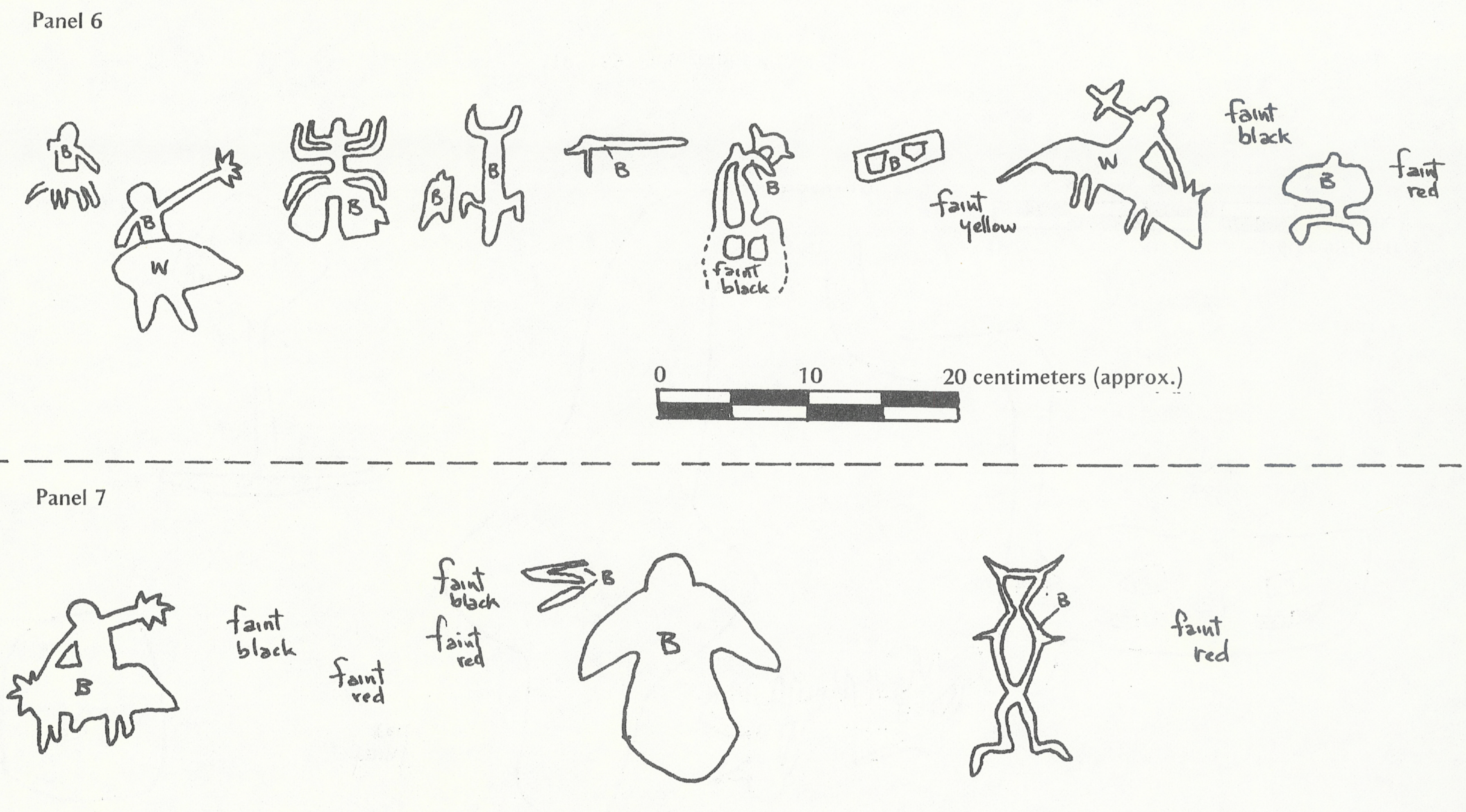
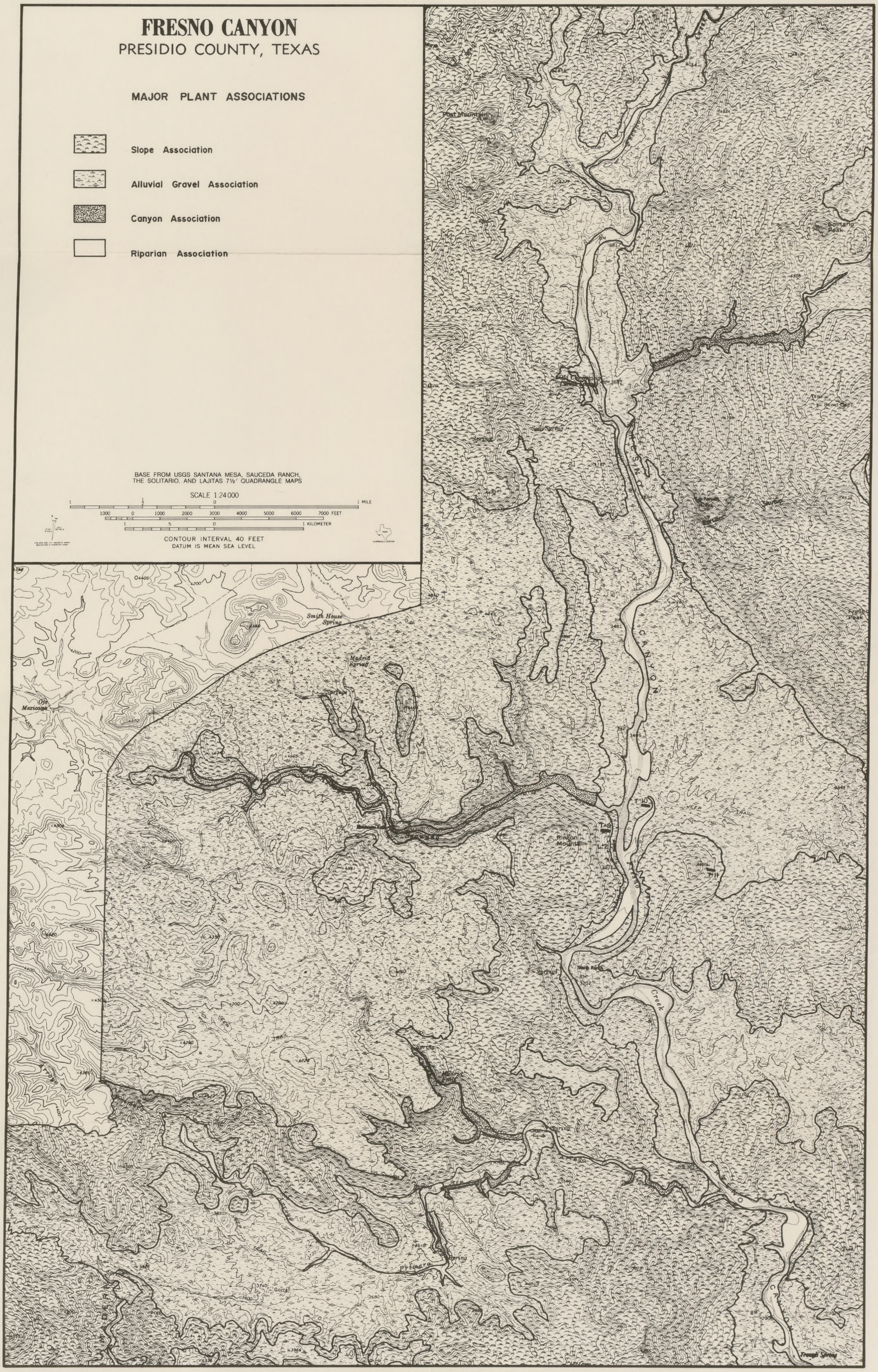


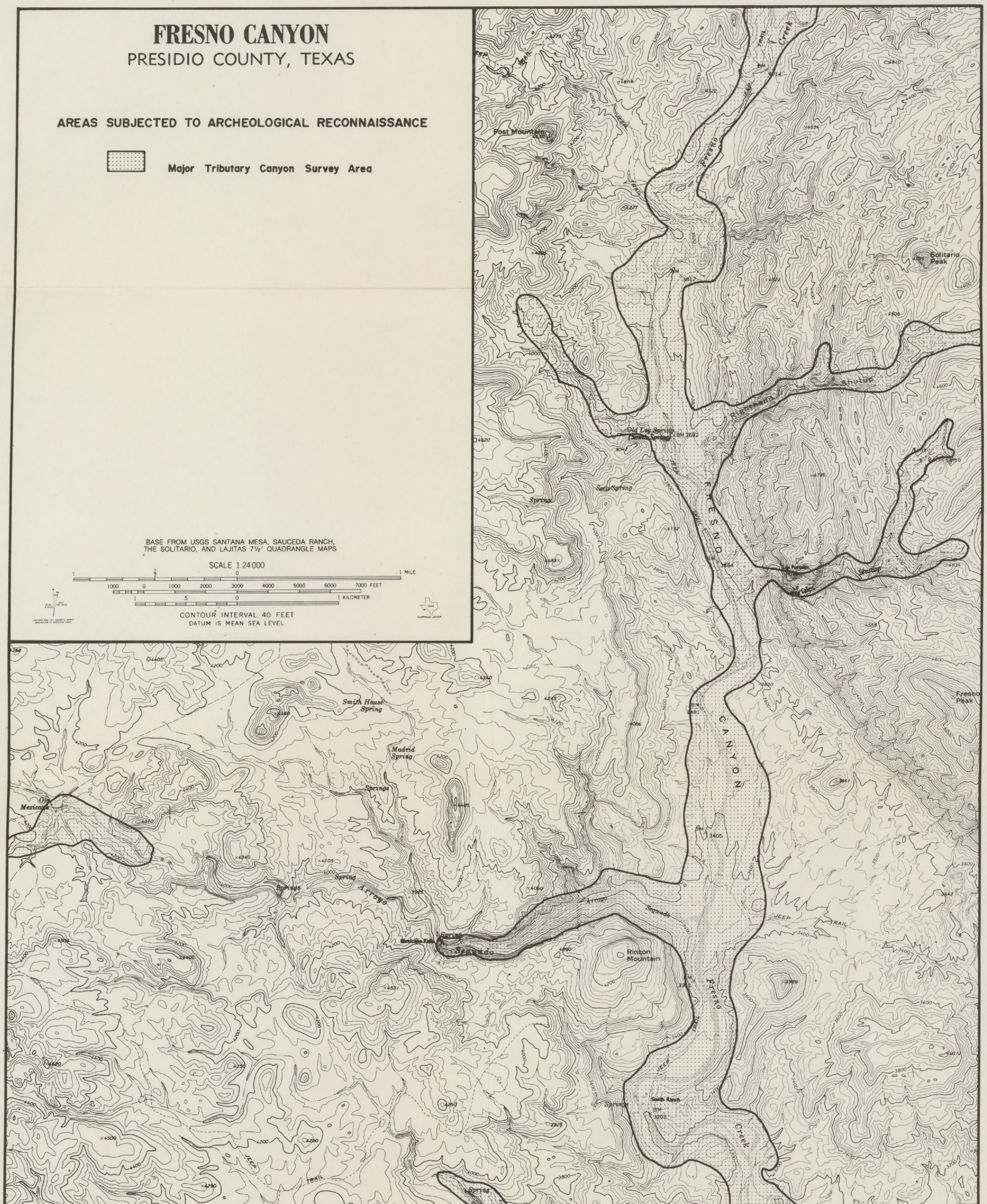
41PS169 Pictographs

FRESNO CANYON

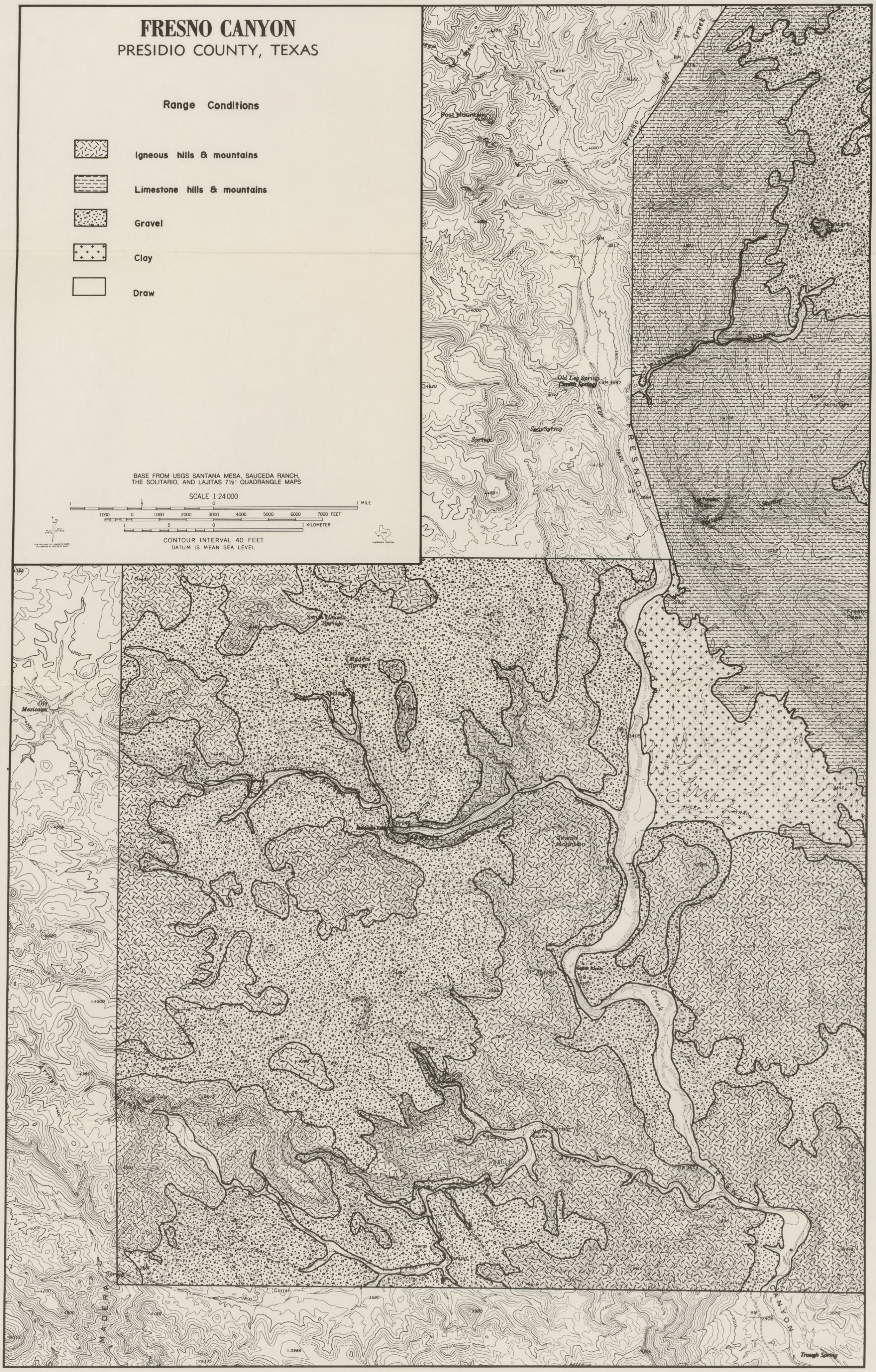
A NATURAL AREA SURVEY
NO. 10

Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin
1976


FRESNO CANYON
PRESIDIO COUNTY, TEXAS
MAJOR PLANT ASSOCIATIONS
Slope Association
Alluvial Gravel Association
Canyon Association
Riparian Association
BASE FROM USGS SANTANA MESA, SAUCEDA RANCH,
THE SOLITARIO, AND LAJITAS 7½′ QUADRANGLE MAPS
SCALE 1:24000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
Smith House Spring
CANYON



FRESNO CANYON
PRESIDIO COUNTY, TEXAS
AREAS SUBJECTED TO ARCHEOLOGICAL RECONNAISSANCE
Major Tributary Canyon Survey Area
BASE FROM USGS SANTANA MESA, SAUCEDA RANCH,
THE SOLITARIO, AND LAJITAS 7½′ QUADRANGLE MAPS
SCALE 1:24000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
Post Mountain
Solitario Peak
Old Log Spring
Fresno Peak
Smith House Spring
Madrid Spring
Rincon Mountain
Smith Ranch
FRESNO
CANYON
Trough Spring


FRESNO CANYON
PRESIDIO COUNTY, TEXAS
Range Conditions
Igneous hills & mountains
Limestone hills & mountains
Gravel
Clay
Draw
BASE FROM USGS SANTANA MESA, SAUCEDA RANCH,
THE SOLITARIO, AND LAJITAS 7½′ QUADRANGLE MAPS
SCALE 1:24000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
Post Mountain
Old Lee Spring
Fresno Creek
FRESNO
CANYON
Madera
Trough Spring